

THE DEVELOPMENT OF A METHOD FOR GENERATING PATTERNS
FOR GARMENTS THAT CONFORM TO THE SHAPE OF THE HUMAN BODY

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By

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DEDICATED TO MY WIFE IRIS

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BY SHRAGA EFRAT

ABSTRACT

This thesis is an account of an investigation into the problems associated with the production of patterns to ensure a garment of satisfactory fit.

Essentially, the method described in this thesis consists of defining a number of crucial shaping points on the body and measuring their spatial co-ordinates. A method is then developed which translates these three-dimensional co-ordinates into patterns whose shapes are such that when joined together with darts suitably positioned, the two dimensional pieces of cloth cut from them are transformed into a three-dimensional garment of accurate fit.

A computer program has been developed which will:

- (i) read the three-dimensional co-ordinates of the human body,
- (ii) calculate the accurate angle of dart needed to be inserted into the pattern to convert it into a three-dimensional 'shell',
- (iii) plot a full size skin and/or block pattern which when sewn into a garment will fit the measured body perfectly.

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PART A

STATE OF THE ART

CHAPTER ONE

INTRODUCTION

There is a great lack of evidence about the exact time in history when man first covered his body with clothing, but it is generally accepted that clothing was first worn before 2500 B.C. and since that time, man has always needed clothing.

Further evidence has shown that until the invention of woven material, which was initially made of flax in about 4500 B.C., animal skin provided the material from which clothing was made. Cotton cloth was known to be used for man's clothing as early as 3000 B.C. (1).

From ancient frescos it can be seen that clothes that fitted the body were worn in many early civilisations; for example, the ancient Egyptians (about 3000 B.C.) wore a loin cloth made of woven material which was wrapped around the body several times and kept in place by a girdle. Most early clothing was of the loosely fitted, draped type of garment, which served man for many centuries. As time passed, more close fitting skirts and other types of garments became common alongside the draped type of garment (2). The development of these close fitting garments was the essential factor in the growth of the craft of tailoring since it was necessary for this garment to 'fit' the human body.

From early medieval times, the tailoring craft became known as a very skilled one, recognised as a strictly 'hand-made' craft, a craft which skill and man-power were the basic elements of its technology. So it remained for centuries and well into the middle of the 18th Century, the practise and techniques remained the same.

In those days, the human body was measured either with a measurement taker (3) which was a long and narrow strip of parchment or paper on which the measurements were recorded; or by a draping method whereby fabric was wrapped around the body and thus attained its shape and size directly. The details obtained from either of these methods were then transferred directly to the cloth from which the garment was to be made. Later, patterns were produced on paper and then laid onto the fabric. The fitting of the garment to the human body was achieved by altering the shape of the pattern when necessary to suit the tailor's measurements; hence this process came to require skill and experienced manpower to obtain patterns which would produce a garment to accurately fit the body.

From the middle of the 18th Century, the development of a tight fitting garment of elaborate design caused increasing interest and concern to obtain more reliably, garments of a good cut and fit and it was realised that previous methods of pattern measurement were inadequate.

So began the search for a system whereby a tailor could draft out garments which would fit well and yet retain their style and elegance. This search led to the invention of the standard tape measure, which was generally accepted in the second quarter of the nineteenth Century.

The usage of the tape measure which was a yard long and marked out in inches, drew attention to the comparative relationship that exists between the various parts of the body. By realising that there is a relationship between breast measurement and length to waist, chest width, back and scye measurement, a new approach to the production of garments was introduced, whereby drafting systems were used, based on

the application of geometrical rules and the principles to the anatomical proportions of the human figure. This was the breakthrough into the more sophisticated tailoring profession that is known to us today as the clothing industry.

By the start of the 20th Century, a new important development had been introduced into the tailoring industry. The increased awareness by the general public for fashion clothing led the way to a new practice, whereby tailors were assembled to work under one roof. This kind of organised 'mass production' used the tailor's individual skill, where he was still producing the whole garment from design to making up, but using the drafting methods which were, by then, available. Thus the manufacturing of clothing developed to an industrial scale as distinct from the 'cottage industry' of previous times, where people worked in their own homes.

By the end of world war II, market demands had been changing considerably. Changes in attitude and behaviour of the population had a great bearing on the tailoring craft - a craft which by then had begun to disappear. The new generation of liberated women who were now dominating the market, discarded the ways of their mothers and grandmothers by choosing simple and free styles of clothing which were far more easy to produce and were quite different from previous pre-war styles. This liberation of the feminine sex was sufficient to move the focus of garment production from mens-wear to ladies-wear, whereas in previous generations the reverse was the case. These changes made the industry realise that their manufacturing methods, technology and techniques, together with small premises and unskilled work-force, were out of date and changes had to come if they were to be able to cope

with these new market demands.

One of the main difficulties which had to be overcome by the manufacturers was the absence of skilled labour. To overcome this problem, a work-force and production engineers from other industries were employed to build up production lines for producing garments of simple and free styles.

The new techniques were based upon methods of production engineering which were established during the war for production line construction, whereby all the manufacturing operations were method studied and had to be completed in the shortest possible production time, providing that the required quality standards were maintained. To achieve this, 'production lines' were introduced whereby all the manufacturing operations previously carried out by the tailor, were now performed by a number of machine operations.

To make this 'piecework' efficient, before putting any style into production, timings for every operation required to produce the garment, had to be estimated to the nearest second. In addition, such mass-production methods meant that it was absolutely essential for there to be no alterations or reshaping of garment parts subsequent to the cut garment leaving the cutting room.

In addition of course, it was of extreme importance for the cut pieces to be of the required shape and cut with accuracy, if the finished garment was to be acceptable as far as body fit was concerned. To meet this requirement, the concept of pattern shaping has been developed, the shaping of the piece being such that when sewn together, they created a

three-dimensional shell, of shape equivalent to that required to fit the human form.

There have been many books (4, 5, 6, 7, 8) written on this subject of pattern construction and shape, some of which are concerned with methods for bulk manufacturing whilst others are specific to the made-to-measure market, but all aiming to produce patterns from which a garment of good body fit can be achieved. The common practice is to develop styles from a 'block pattern'. This is a basic pattern, consisting of the back, front (and sometimes sleeves) of each fashionable silhouette omitting all style features.

Cain (9) and others emphasised that the fit of a garment is directly associated with the accuracy of the manufacturer's basic block pattern. Style has nothing to do with fit. The basic block pattern serves as the yardstick from which all designs are made and measured. Without this block pattern, fashions could not be mass-produced because of the inaccuracy of the fit. In addition, the block pattern with accepted standard modifications to achieve fit for different sizes (known as grading) permits theoretically good fitting garments for all sizes.

Today, when fabrics are so expensive, it is the common practice for the garment pieces to be cut according to a previous accurately prepared pattern. There are various ways of obtaining the pattern as described below. These methods were devised in the early days of the tailoring craft, and were designed to serve the needs of a busy tailor who required a guide when producing a garment (10).

The aim of all pattern construction methods is to produce as perfect a garment as possible to a basic standard of fitting quality. In the case of the made-to-measure trade, a ratio of one customer to one garment is the practice, and a good fit of a garment should be provided. In the case of the ready-to-wear trade, the aim is to produce a garment that will be of a fair to good fit, on a large number of people of a similar size.

One method for producing patterns is by the use of a modelling technique. Modelling is the name used to describe the art of draping fabric on a form and manipulating it in such a way as to mould it to the contour of the figure.

One way is to build up the design gradually on the stand or figure by cutting and draping each section of the design piece by piece. However, the most practical of all modelling methods is that of fitting the human body or the form with a muslin or fabric 'shell'. This method is more efficient and more effective because the fitting and designing are carried out simultaneously (11). Furthermore, full co-ordination of construction lines with body lines are demonstrated and therefore when

pattern pieces are sewn together, the garment should be identical to the original model. In today's industry, modelling is used in the couture section, where a single garment is required in an exclusive design and where the final garment has been considered to fit as accurately as possible, the purchaser of the garment.

1.2.2 DRAFTING METHODS

Another means of producing patterns, commonly used in the bespoke section of the industry are drafting methods, which are employed to construct the basic 'block pattern' without the direct aid of the modelling techniques.

(i) Direct Measurement

There are two drafting methods in use in the industry. One of them is known as the 'direct measurements' whereby measurements are taken from one point to another on the body itself by using a tape measure. The measurements thus obtained are then applied to produce a flat, two dimensional pattern.

This is accomplished, in the case of the made-to-measure trade, by taking measurements direct from the body to be fitted and applying them in such a way as to produce the pattern outlines which the tailor's experience and skill tells him will come nearest to providing a satisfactorily fitting garment. In the case of the ready-to-wear trade, the common practice is to work to an 'imaginary' perfect figure, the measurements of which are decided by taking an average of many figures of similar bust size. These are the measurements used to construct the size chart.

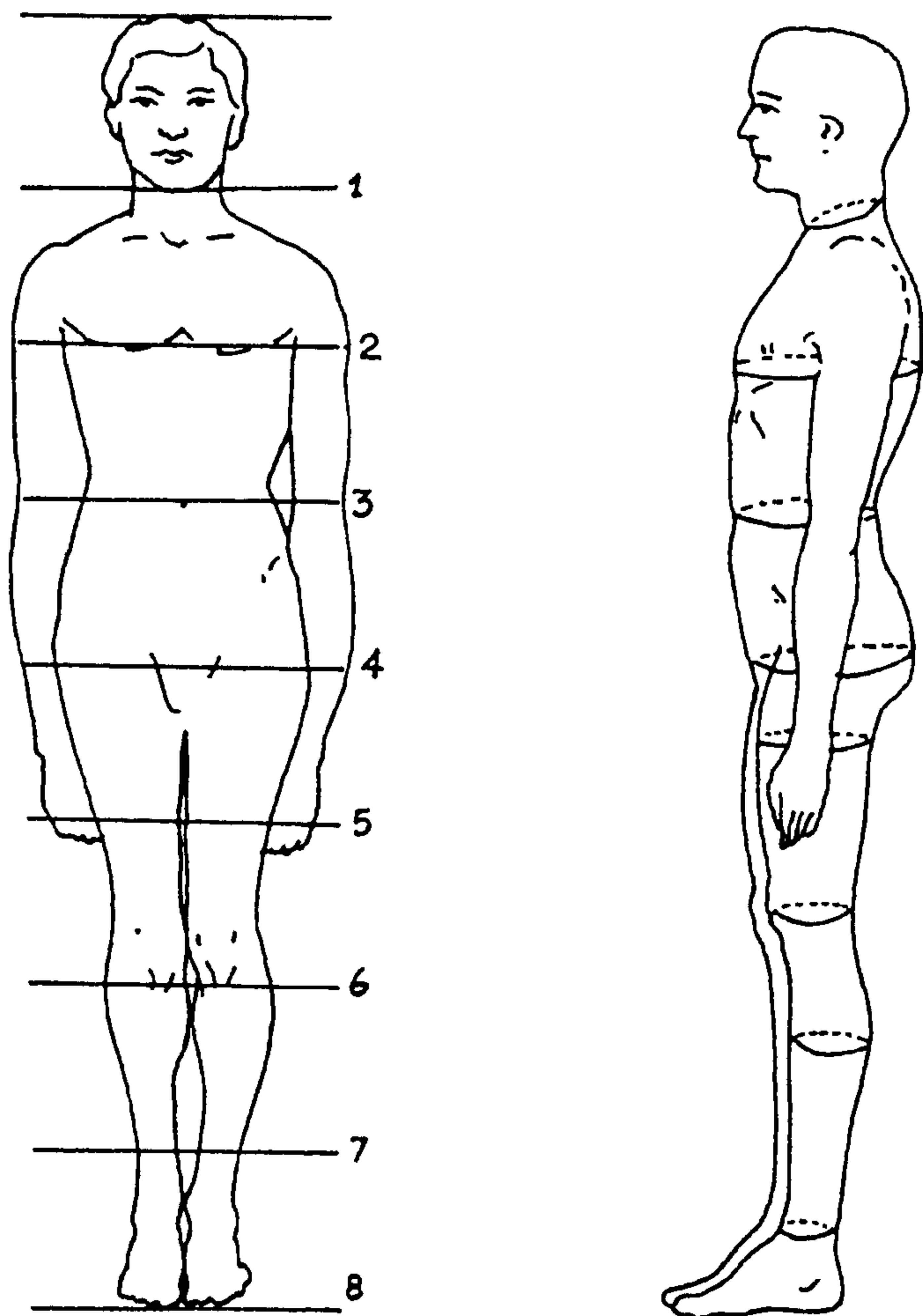
This method, however, is fraught with inaccuracies and places too much responsibility on the tape measure. The tape measure in the hand of any but the more experienced craftsman, can be very unreliable.

It is generally recognised (12) that the errors associated with the use of the tape measure are related to the unsuitability of the instrument for the job of accurately measuring distances on the human form. For example, it is very difficult to locate the exact point from which a given measurement should be taken, thus leaving the measurer the option of placing the tape in the wrong position. Furthermore, customers are notorious for altering their natural attitude when being measured with the result that the direct measurements of the figure may be just a record of the body in an unnatural stance.

(ii) Proportionate measurement method

Another method of drafting is the one known as the proportionate measurement. Artists and others (13) have realised for a long time that the proportion of the normal human body may be represented by the height of the figure being divided into eight equal sections (see fig. 1).

This method had been applied to the construction of patterns after tailors discovered that certain body measurements such as armholes, neck circumference, etc., were difficult to obtain with a tape measure and the proportionate method seemed to offer a ready solution to that problem. Using this method a working 'scale' is



DIVISION OF THE HUMAN FORM INTO EIGHT EQUAL SECTIONS

FIG. 1

arrived at whereby one can use it to compute the relative values of the depth and width factors in relation to the bust girth. It has to be understood that this method can only be expected to work when the figure to be fitted has normal proportions and even then it is quite clear that the 'idealised' concept of the human form is not an exact method for individual cases in which to obtain garments of the same size as the body they are intended to fit. As such, the method is not as widely used as the direct measurement method.

Apparel production presents special problems in so far as the relationship between body shape and pattern shape are concerned. In order to achieve well shaped pattern pieces, technology and products have to be adapted to accommodate the shape of the human body which is a very complex shape to determine. Theoretically, clothing manufacturers have to fit 99% of the population, which means that virtually every step of production from design concept to fitting sessions influence the final fit of the garment (14).

It will be appreciated that if a well fitted garment is to be produced, well shaped pattern pieces are required which can only be produced if accurate body measurements have been obtained.

Today, the chances of manufacturing a well fitted garment are considerably improved than they were fifty years ago. In those days co-operation between industry and government agencies were lacking in so far as surveys of body dimensions were concerned, and every clothing manufacturer had their own table of body dimensions obtained from unsystematic, unreliable and unscientific trial and error methods (15).

The first scientific study of the woman's figure was an anthropometric survey carried out in 1926 by Berlei of Australia. In this survey twenty six measurements were taken from 5,000 Australian women aged between 15 and 65. These results which were first collated and analysed between 1926-1928, have been reviewed in 1976 and when found valid, an 'average' woman's figure was produced (see Fig. 2).

MS AVERAGE AGE 34

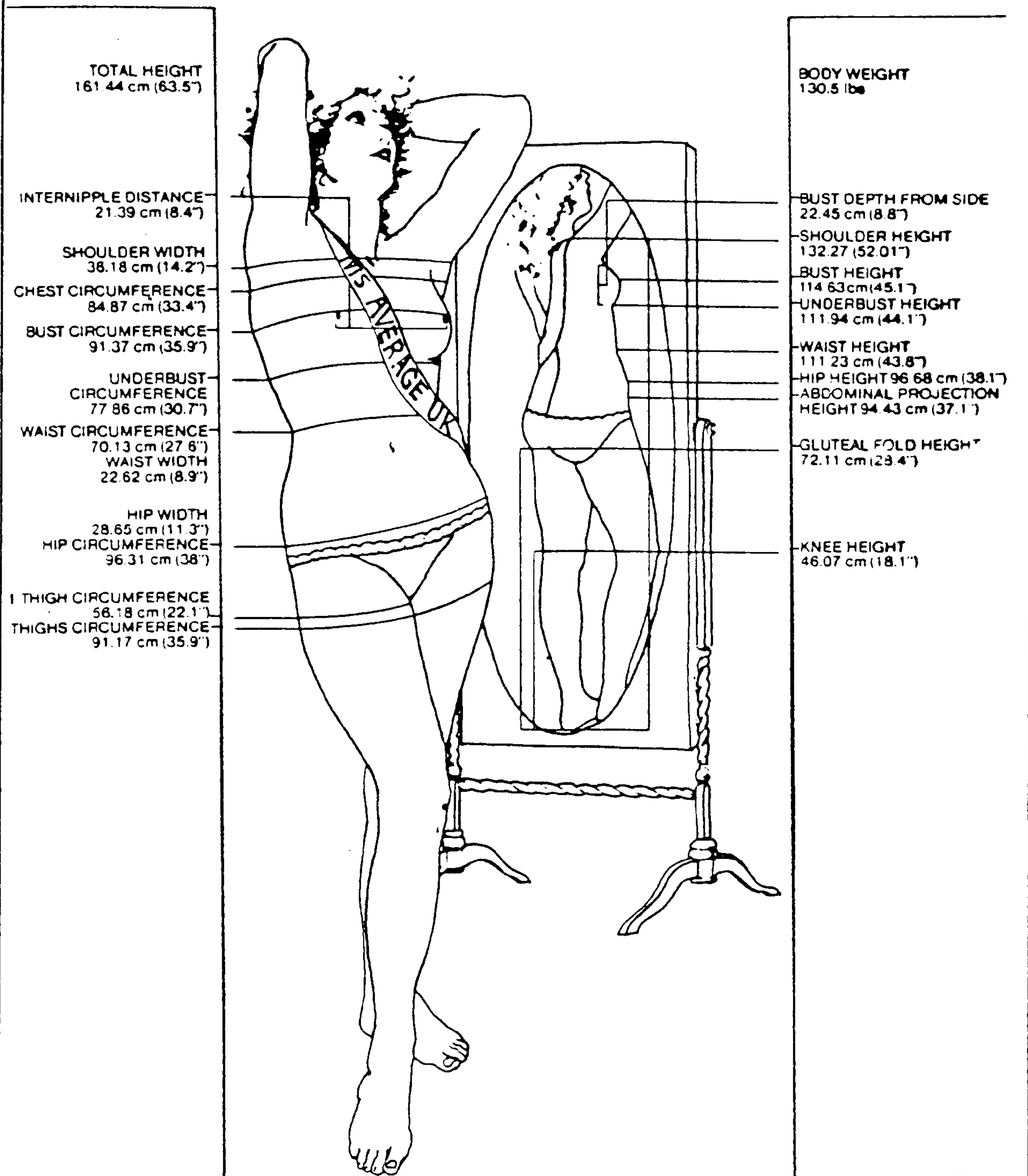


FIG. 2

The second move made towards establishing a scientific set of body measurements began in 1941 with a comprehensive anthropometric survey carried out by the U.S.A. Department of Agriculture. Nearly 150,000 children between the ages of 4 and 7 and nearly 15,000 women were measured systematically and scientifically and a full set of reliable data on body measurements was obtained (16).

From the set obtained, three types of commercial standards were produced which can be grouped as follows:

- (i) Body measurements standard - which represented the body measurements taken from the subjects whilst wearing foundation garments.
- (ii) Model form standard - which was girth and length measurements suitable for the fitting of outer garments.
- (iii) Garment size standard - which was derived from body measurements for specific garments.

Since that survey, the only large scale anthropometric survey of the American female was a survey carried out in 1946, which provided comprehensive body measurements of the female military population. Table no. 1 shows a summary of female anthropometric studies carried out in the U.S.A. between the years 1939 - 1978 (17).

The first and largest inquiry yet into body measurements in the U.K. was carried out in 1943 by the Ministry of Food. In this survey, 30,000 people, male and female of all ages were weighed and measured for height (18). The two dimensions obtained have been of considerable importance, since to a limited extent, the other body measurements required may be predicted from them.

<u>Date</u>	<u>Study Population</u>	<u>NO</u>	<u>Data</u>
1939-1940	Civilian women	14,698	59 measurements
1942	USAF women		31 measurements
1946	Army women	8,859	64 measurements
1952	USAF women	852	63 measurements
1959-1962	Civilian women - N.H. examination	3,581	18 measurements
1968	USAF women	1,905	136 measurements
1971	Airline FA women	423	72 measurements
1976-1977	Army women	1,331	128 body size dimensions

TABLE 1

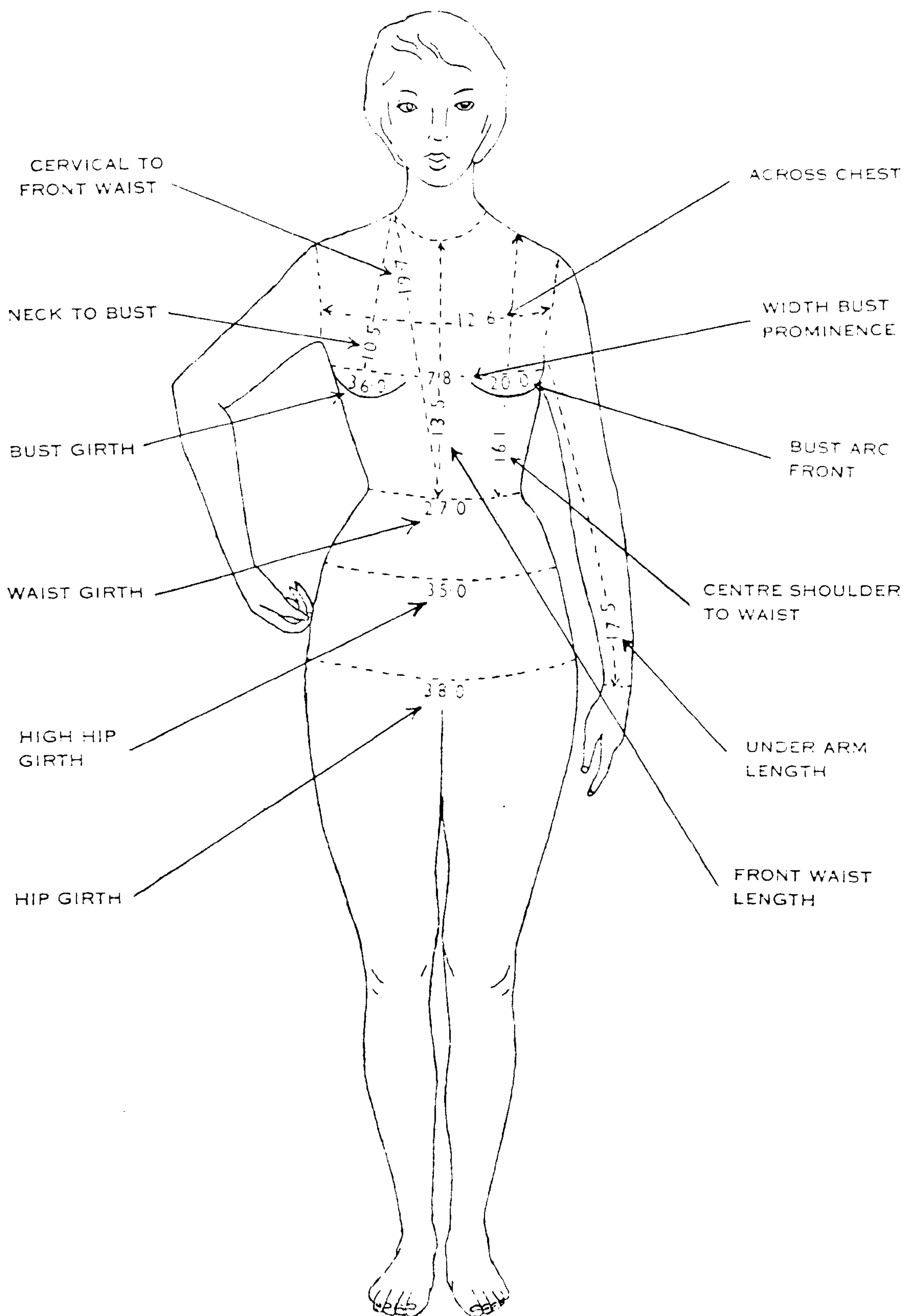
Summary of Female Anthropometric Studies

The second large scale survey of a civilian population in the U.K., was the J.C.C. survey, which was the only large scale survey designed to date especially for the clothing industry (19). In this survey, nearly 5,000 women between the ages of 18 - 70 were measured and forty two measurements were taken on each individual. (see Figs. 3, 4, 5). The results of this survey were size charts produced for tall, medium and short women of different bust and hip ratios.

The armed forces have also carried out surveys of body measurements, notably the Royal Air Force (20) and the Royal Armoured Corps. (21). These surveys however, were made in order that cockpits and combat crew clothes could be designed and hence were exclusive to male figures. Consequently, they are not relevant to the construction of garment patterns for women's clothes.

Of the various surveys, only the J.C.C. survey is complete in all details required for the production of patterns for clothing purposes. In practice however, manufacturers base their production on a table of measurements known as a 'size chart' which represents the standards that their company will adhere to in order to meet the particular requirements of a segment of the population at which they are aiming their product. This being the case, it is clear that there are many different size charts in use which are in existence to cater for the many different markets and which are not based on scientific surveys of body measurements and therefore would not ensure the production of a well fitted garment.

* It was pointed out by the external examiner that recently WIRA have conducted a limited survey of the british male population as regards body measurements appropriate to garment production. The author was aware of this work but had not been able to obtain information about it. It is understood, however, that this information is now available as a report (50).



MEASUREMENTS TAKEN IN THE J.J.C. SURVEY (FRONT VIEW)

FIG. 3

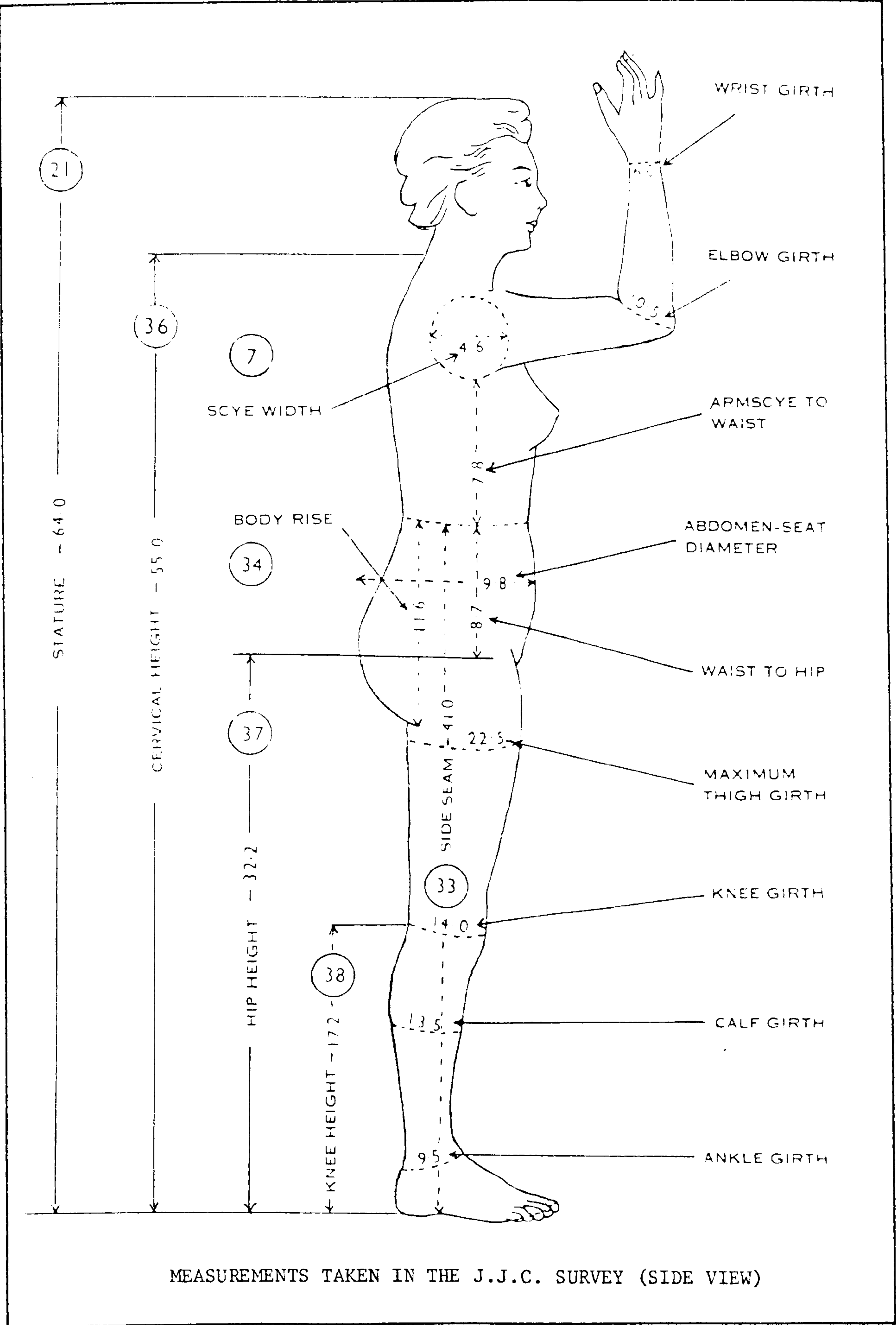
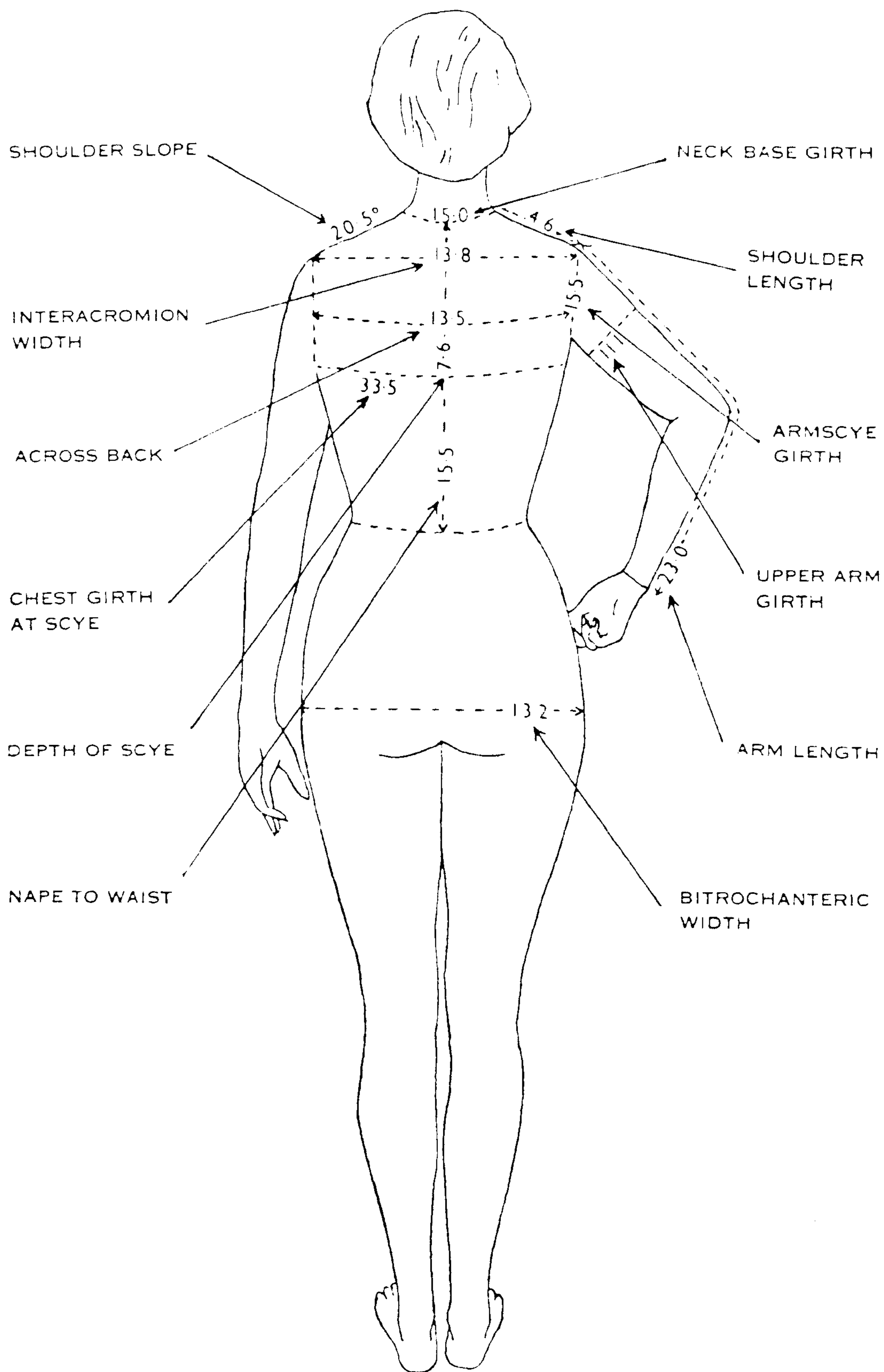


FIG. 4



MEASUREMENTS TAKEN IN THE J.J.C. SURVEY (BACK VIEW)

FIG. 5

CHAPTER TWO

THE ASSESSMENT OF BODY SHAPE

As described above, when using patterns for the production of garments, it is the practice to make use of what is commonly referred to as a 'block pattern'. It is apparent that the shape of the garment and hence its ability to fit the form, depends entirely on the 'block pattern' consisting of accurately shaped pattern pieces as well as accurate location of and size of darts.

In the early days, when the cost of material was not important, inaccuracies in the 'block pattern' were dealt with by the allowance of spare fabric which on 'fitting' or 'alteration' could be incorporated into the garment to achieve a more accurate fit. Currently, in the ready-to-wear trade, where prices have become so much more competitive, engineered garments are the accepted standard. No spare fabric can be afforded so that it becomes essential for the pattern to produce a garment which fits the human body correctly. Hence, whichever method is used to produce the basic or block pattern, its effectiveness is determined entirely by the accuracy in producing a garment which will give an accurate fit.

The fundamental requirement, therefore, is the accurate determination of the three dimensional shape of the human body from which two dimensional patterns will be produced.

In order to accurately determine the shape of a three-dimensional human body, circumferential measurements as presently taken, are not the complete answer to, or solution of, the technical problem of fit.

It has been said (22) that however the circumferential and length measurements may be taken from a human body, and however they may be applied to a pattern, they will not by themselves guarantee a perfect fitted garment since they cannot fully determine the shape of the human body.

The following examples illustrate this point.

Fig. 6 shows a cross section of a bust, waist and hip area of a female body. It is clear from Fig. 6a, 6b and 6c, that, whilst they all have similar circumferential measurements in these areas, the shape of these bodies is quite different and would require different shaped garments to give an accurate fit.

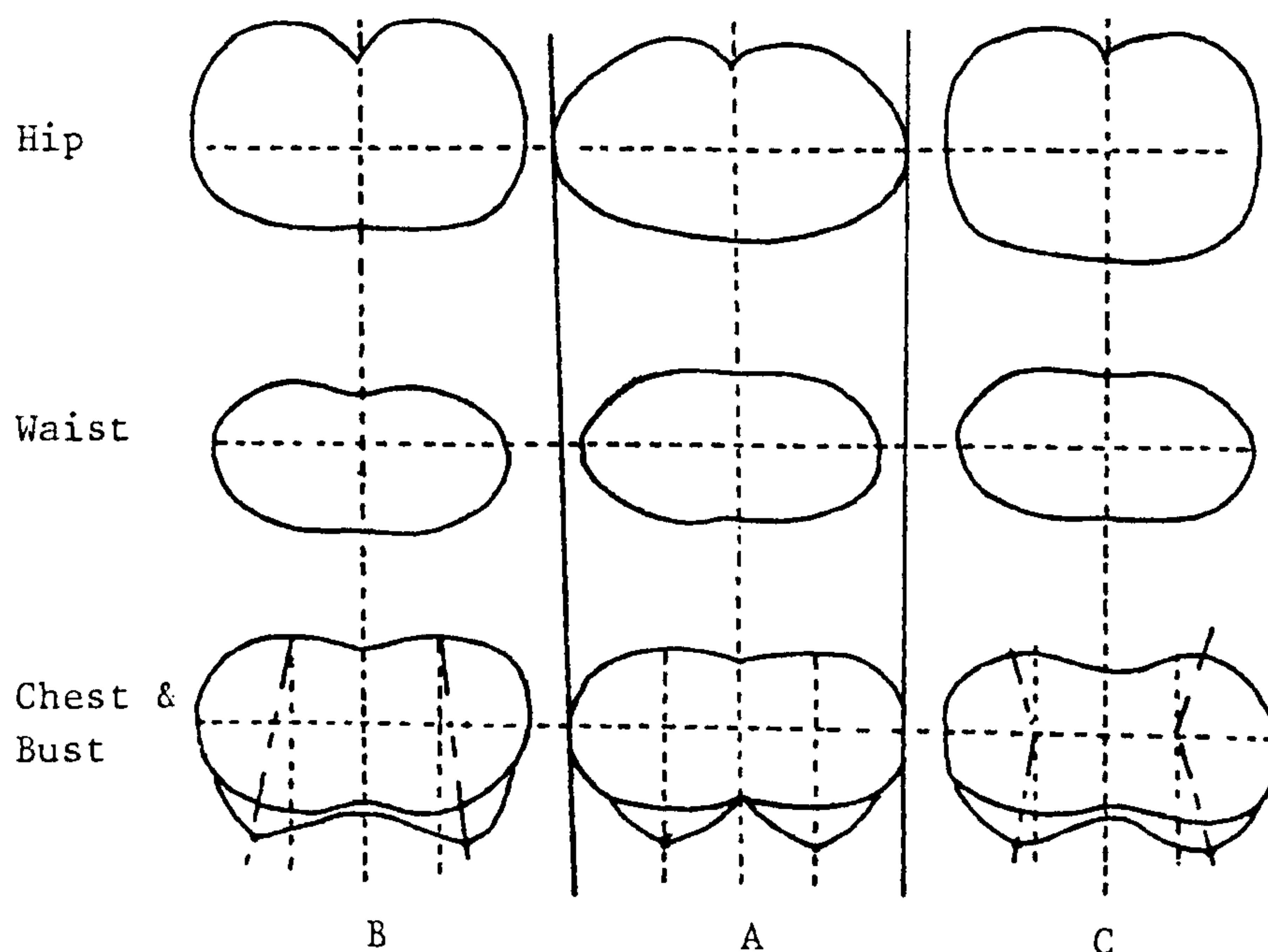


FIG. 6

Fig. 7 shows another example of three different figures of similar circumferential measurements, varying in shape when viewed relative to a vertical line. Fig. 7a shows the shoulder-blade and buttocks touching the vertical line, whereas Fig. 7b shows the same area in the body well within the line. Fig. 7c shows the seat prominence beyond the vertical line and the neck more forward than in the other cases. Again, each of the three bodies to achieve a good and an accurate fit, would require garments different in shape.

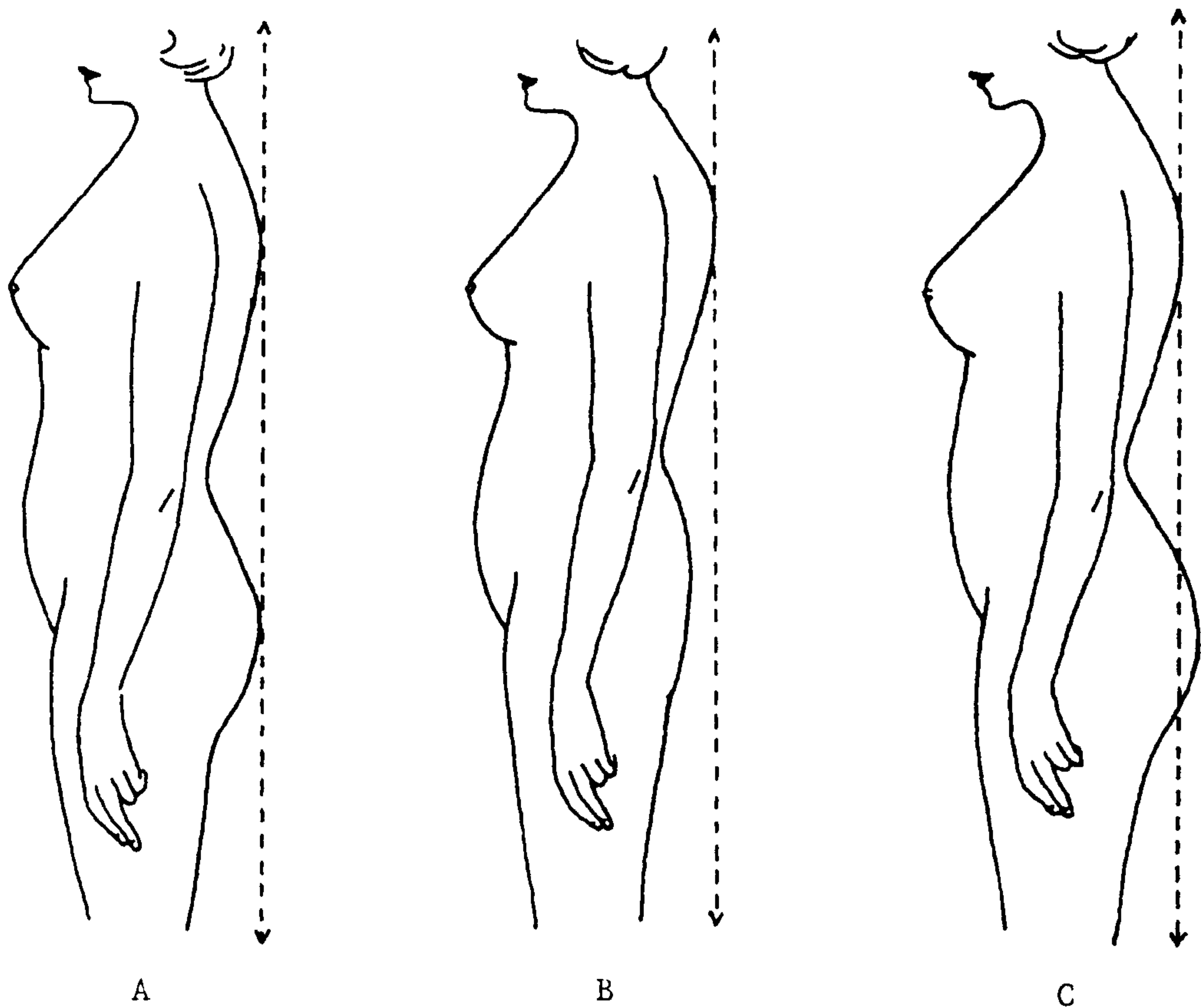


FIG. 7

Fig. 8 shows two anatomical drawings of female torsos having identical waist and bust measurements but again, are clearly different in shape. Fig. 8a is more fleshy between the breast base and the waist line whereas Fig. 8b has quite a different aspect between the same two positions; furthermore, by comparing the outline of the back from point 3 to 4 on Fig. 8a with that from point 5 to 6 on Fig. 8b, one can clearly see that the former might be described as a long waist type, whereas the latter is a short waisted type.

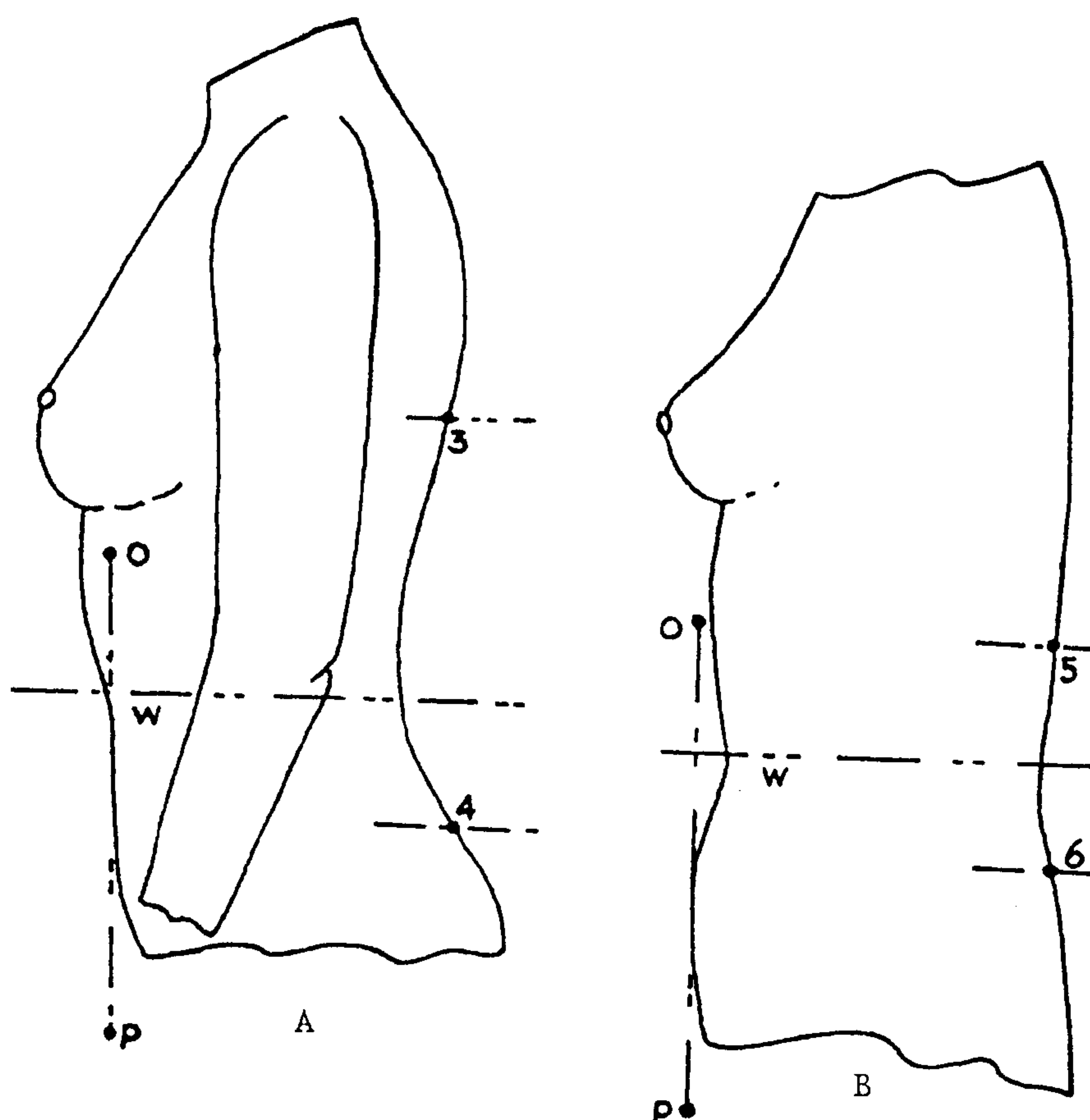


FIG. 8

These examples are being put forward to stress a point of utmost importance - the tape measure, although it is still the accepted measuring tool, does not give an accurate measurement of figure shape.

2.3 PREVIOUS WORK ON BODY SHAPE DETERMINATION

2.3.1 Traditional Methods

2.3.1.1 Made-to-Measure Techniques

Originally, made-to-measure men's wear was produced by an individual tailor, who not only took the measurements of the human body for which the garment was supposed to fit, but personally used the information to cut out and design the garment, to supervise the alterations and to present the final finished garment to the customer. The success enjoyed by the tailor, in producing a garment which fitted well, depended to a large extent, on his expertise with the tape measure and eye when trying to assess the figure shape, and on his knowledge of how to make alterations to the garment to achieve the best fit possible.

Currently, the individual tailor is less commonly employed and most of the made-to-measure garments are today processed through the hands of the large multiple tailoring organisations. The accepted method and sequence of taking measurements for a garment are illustrated in Fig. 9 and are as follows:

1. Cervical to waist at centre back
2. Cervical to full length
3. Across back
4. Half across back to elbow to full sleeve length
5. Chest
6. Waist
7. Hip

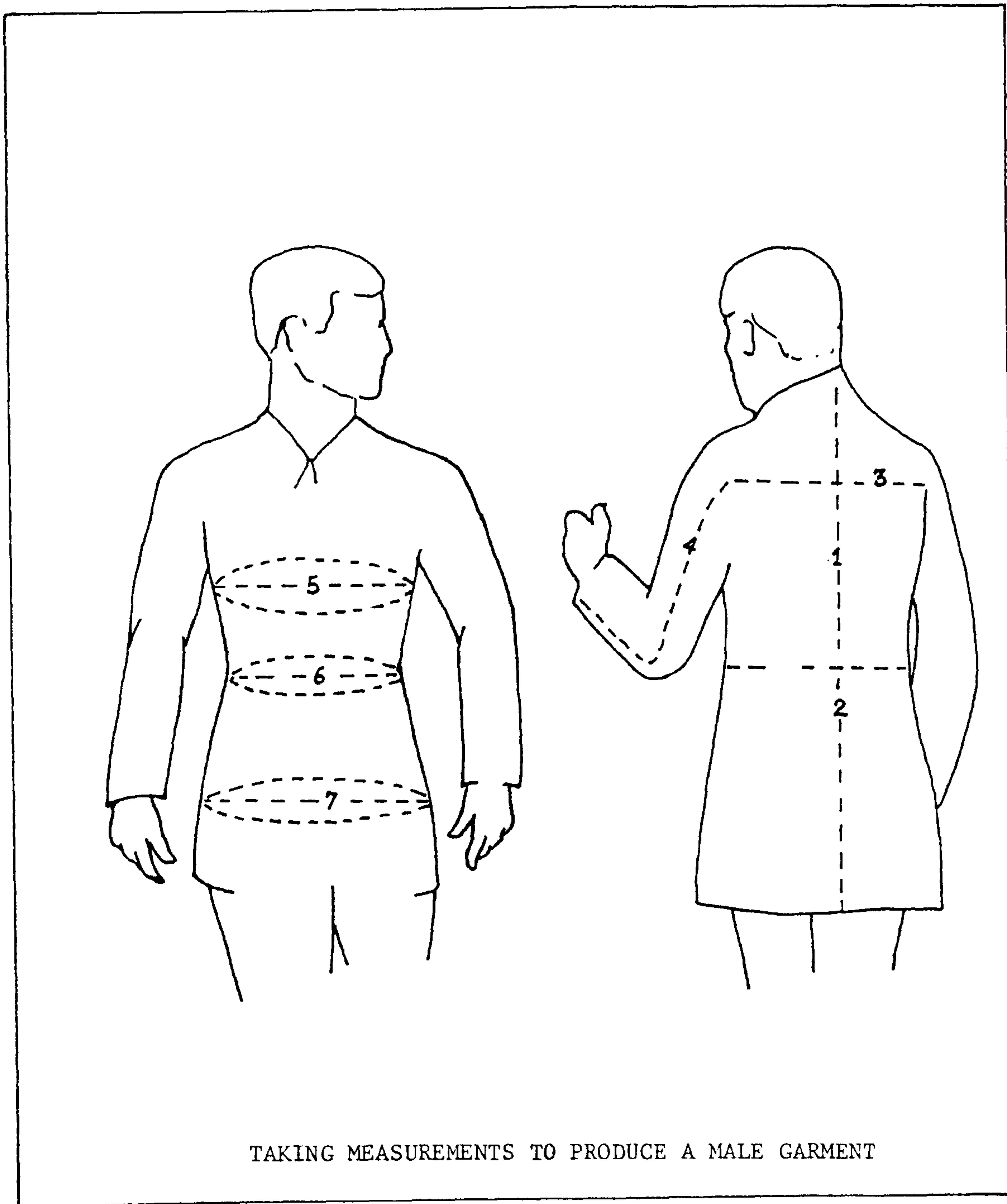


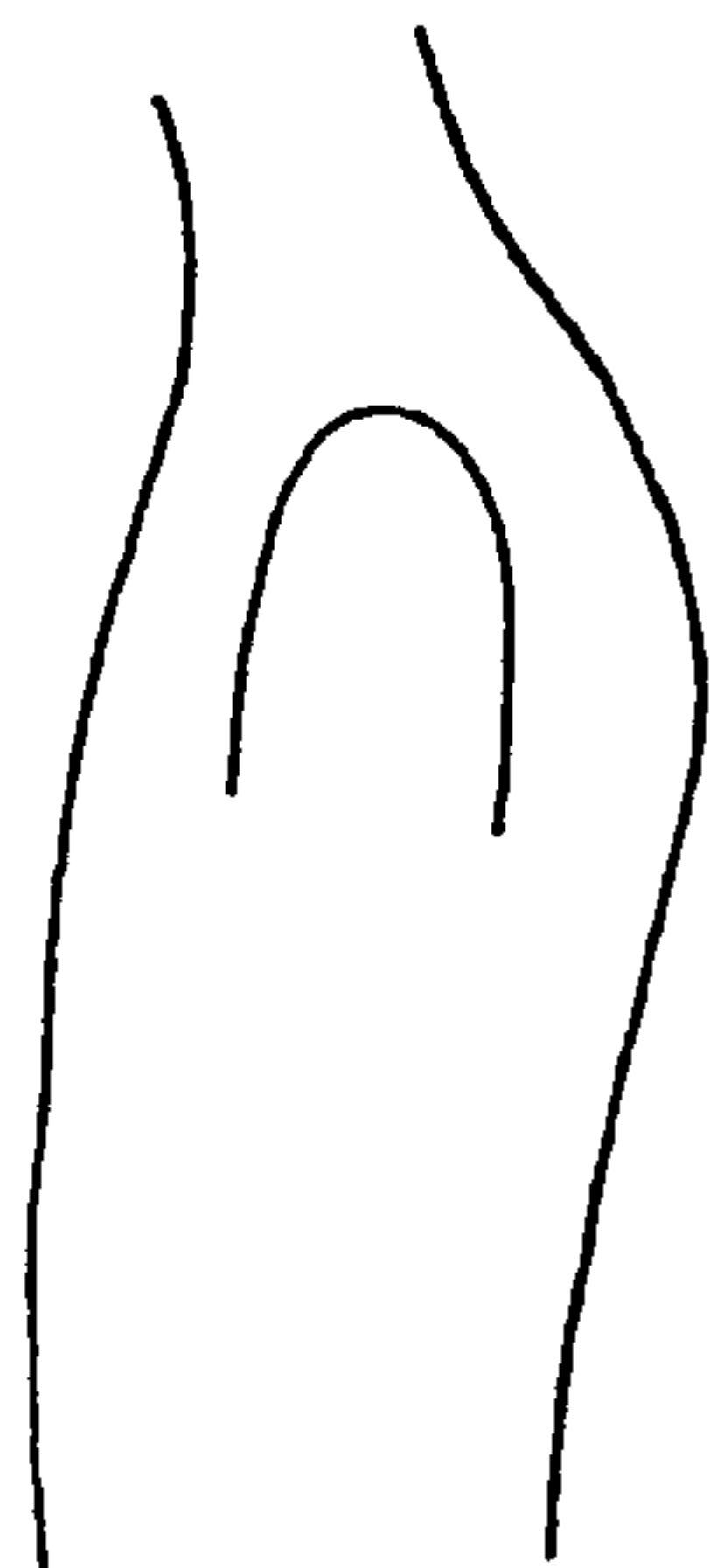
FIG. 9

The practice today is that all the measurements and the visual assessment of the customer's body are carried out by a salesman in the retail shop. All the details required are presented on an order form which contains the customer's measurements, figure type description and details about style, fabric colour, etc. In addition to these measurements, figure shape is then identified by the following descriptions:
(See Fig. 10)

Head forward
Round back
Stooping
Sloping shoulder
Square shoulder
erect posture

Since these measurements, observation and figure type identification are not by themselves enough to determine the body shape, and since they are not taken by an experienced tailor, but by a salesman not experienced in the art, it has been found necessary to support these measurements by the use of prototype garments. The prototype garments are sample garments made to accommodate large numbers of customers with different figure shapes that might come into the shop. The customer, on entering the shop and asking for a made-to-measure garment, is requested to try out a prototype garment which will indicate to the salesman the garment size and shape required to obtain a good fit for this customer. It is well known that up to 60 different sizes and shapes of prototype garments are in stock in each of the 300 shops owned by a large multiple tailoring organisation, to help in the customer's shape definition. (23).

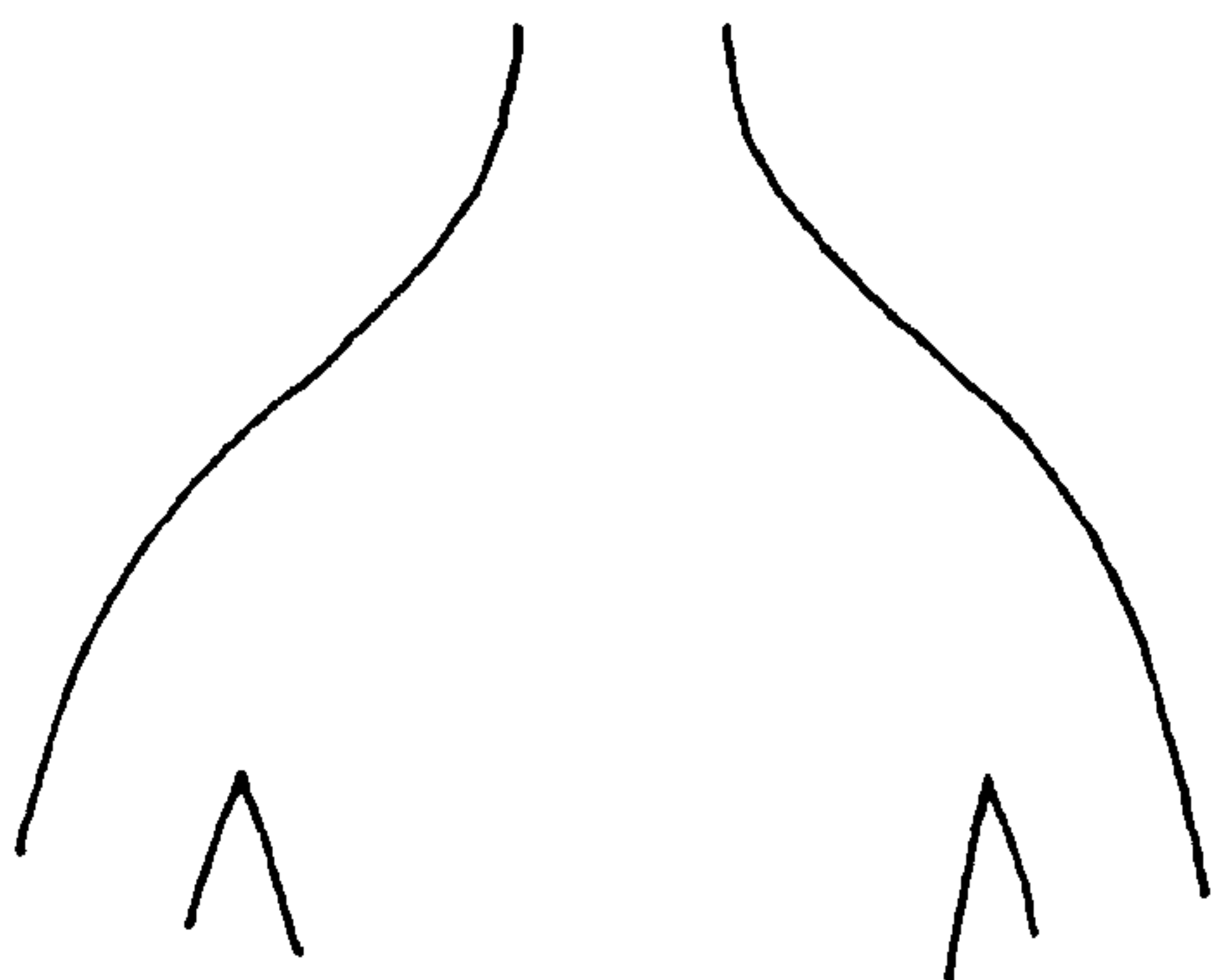
ROUND BACK



HEAD FORWARD



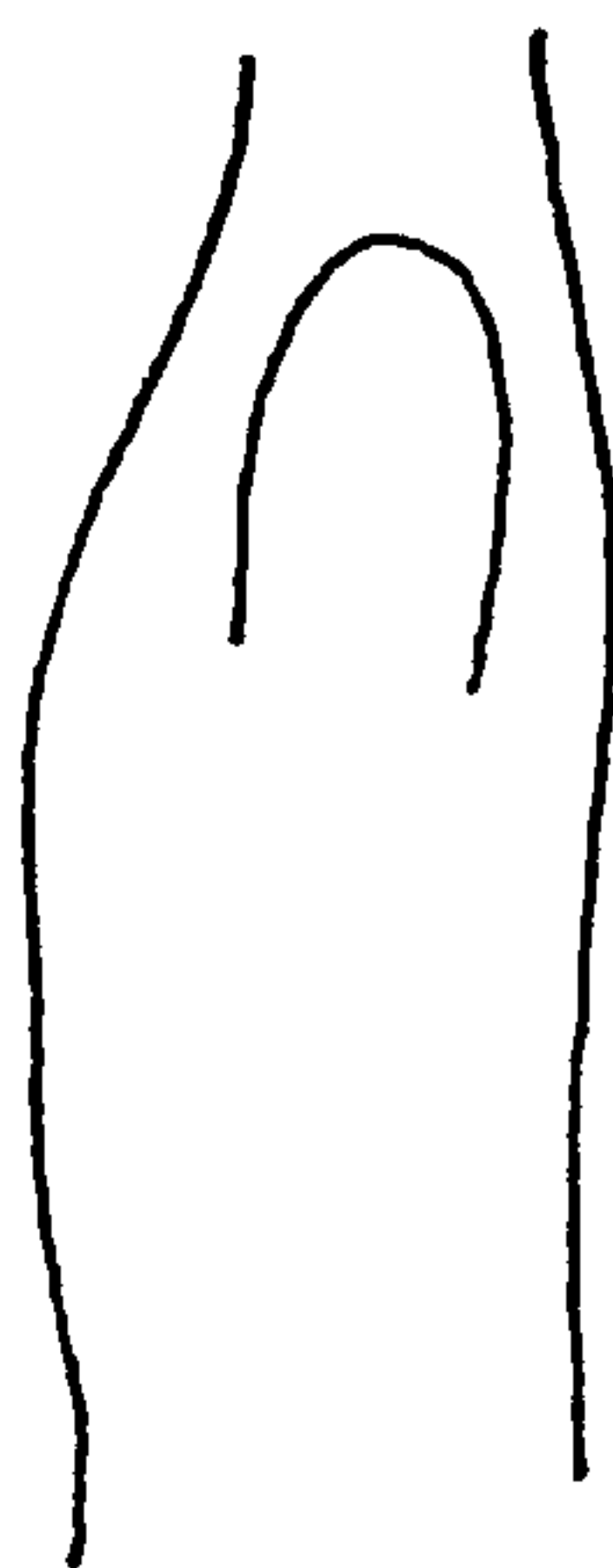
SLOPING SHOULDER



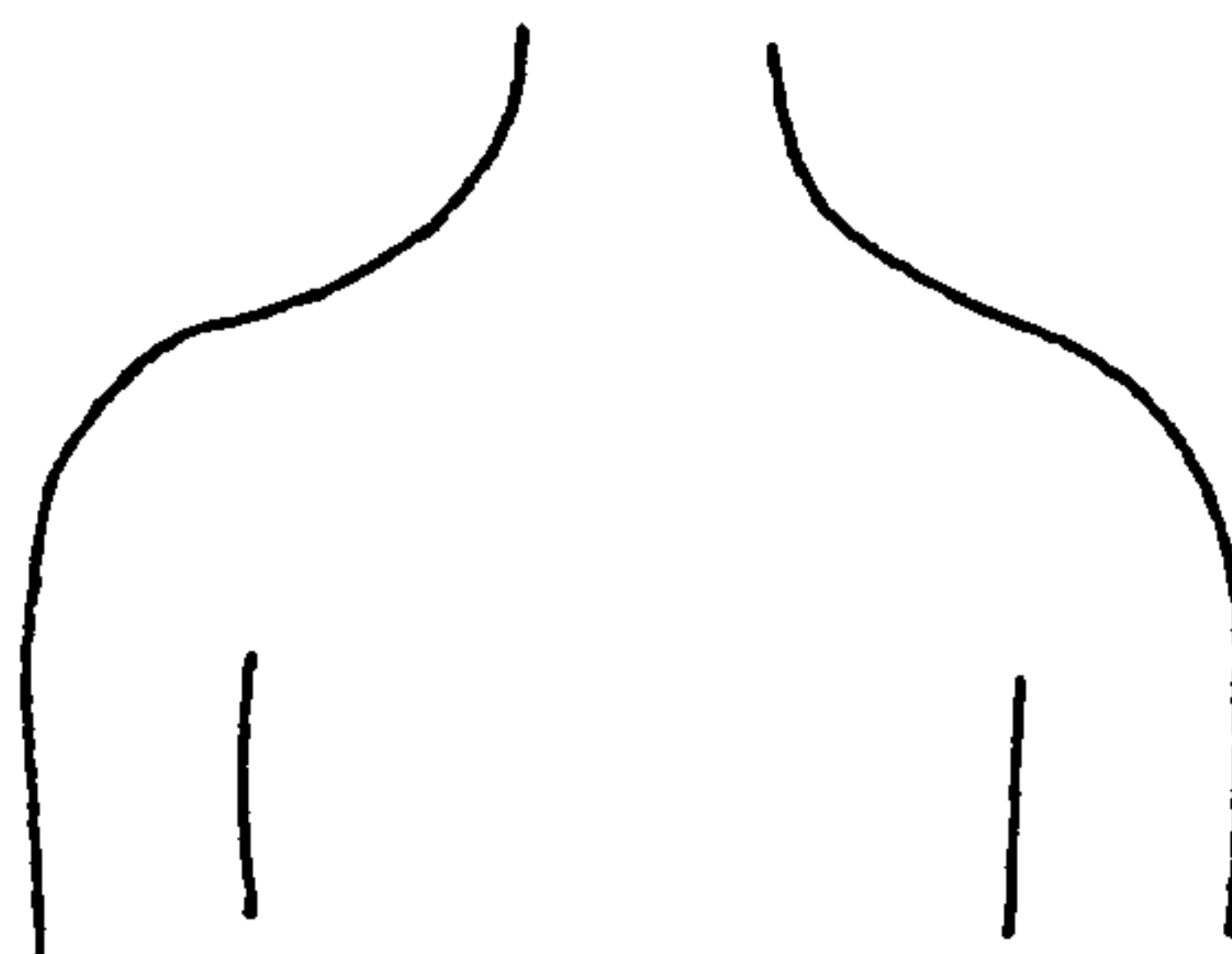
STOOPING



ERECT POSTURE



SQUARE SHOULDER



IDENTIFICATION OF FIGURE SHAPE

FIG. 10

In the women's trade, the assessment of the shape is even more approximate and due to the wide range of styles offered for sale, it is not practicable to have prototype garments available. The alterations needed to reshape the garment parts correctly are consequently more complicated to assess. In fact, the common way today to produce made-to-measure garments for women, is to use the modelling technique, whereby the woman is acting as a model for her own garment.

2.3.1.2 Ready-to-Wear

In the case of the ready-to-wear market, it has been the practice to gather the anthropometric data for the section of the population for which a certain product is being aimed. Based on this data, a master pattern is produced. All style features and lines are then inserted onto the master block to obtain a mass produced style block. The patterns, thus produced, are then sewn together and tried on a human figure for fit. Once the sample garment has been approved, the scaling for sizes is then performed and a sample of each size required is made up. When all the sizes are available, the samples are tried on live models for fit and comfort and after approval the garment can then be mass produced.

It will be appreciated that the fit of the garment is thus decided on one model only, who may or may not be typical of her particular size group, and the fit of the garment will only be assured if the wearer is of similar dimensions to the model used.

The problems of achieving garments of satisfactory fit using modern traditional methods are illustrated by the following statistics:

- (i) Private information (12) has revealed that one large tailoring firm totally replaced 5,000 suits from the production of one factory alone, in a single year.
- (ii) About 10% of all made-to-measure products from a large mail-order firm required alteration because they did not fit well enough. (24)
- (iii) In a large made-to-measure organisation, the total amount of returned goods due to poor fit is about 5%, (25) and this occurred, after using the most sophisticated computer techniques available, to help in the production of those garments.

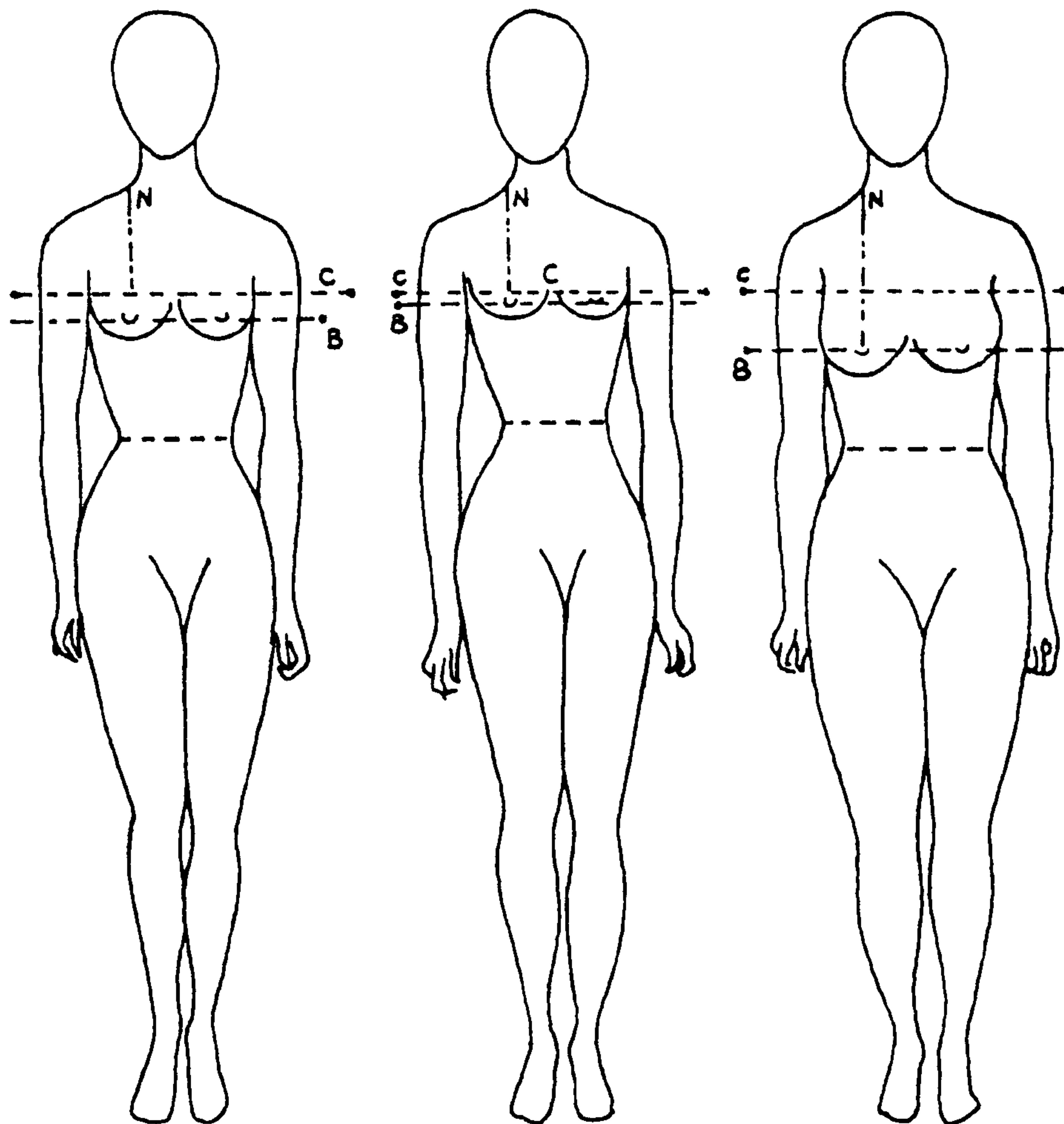
Thus, considering the high cost of garment production and the cost of returning goods, it is quite obvious that it would be of great economic significance if garment parts could be shaped in such a way that a better and more reliable method for achieving a good fit could be assured.

2.3.2 Whife's Approach

As already mentioned in 2.2, Whife pointed out that the measurements usually taken on either a male or female body will not by themselves, guarantee a perfect fitted garment and that an 'observation' and 'judgement' of shapes and contours must be applied in order to achieve a good fit. Apart from these two considerations, a third dimension, that of 'thickness through' of a figure is required to produce well shaped pattern pieces. (See Fig. 12).

The above claim is supported by the following examples:

- (i) Fig.11 shows three female figures which were marked with horizontal lines to indicate chest, bust, waist and hip levels. It is noticeable that although all three figures have exactly the same chest girth and may have the same bust girth, the bust shape clearly differs from one figure to another and the distances between the bust line and chest line are also different. Apart from that, it can be noted that line N on the figures has a different length with each figure and that the distance between the breast and waist lines differ considerably. It is clear from this example that chest and bust girth are not in themselves indicators of chest and bust shapes.



FRONT VIEW OF THREE FEMALE FIGURES OF SIMILAR
CIRCUMFERENTIAL MEASUREMENTS

FIG. 11

(ii) Fig. 12 shows the side view of the female figures. It may be seen that although there is little difference in the actual size of the bust, and they are all of the same chest size, they vary considerably in their shapes. One obvious thing to note is the difference in breast attitude; another is the totally different shape of the figures below the waist line (as may be seen by the line A-W). In addition, it is clear that the shape of the back below waist level is quite different. These facts, if not noted and allowed for, would cause a poorly fitted garment.

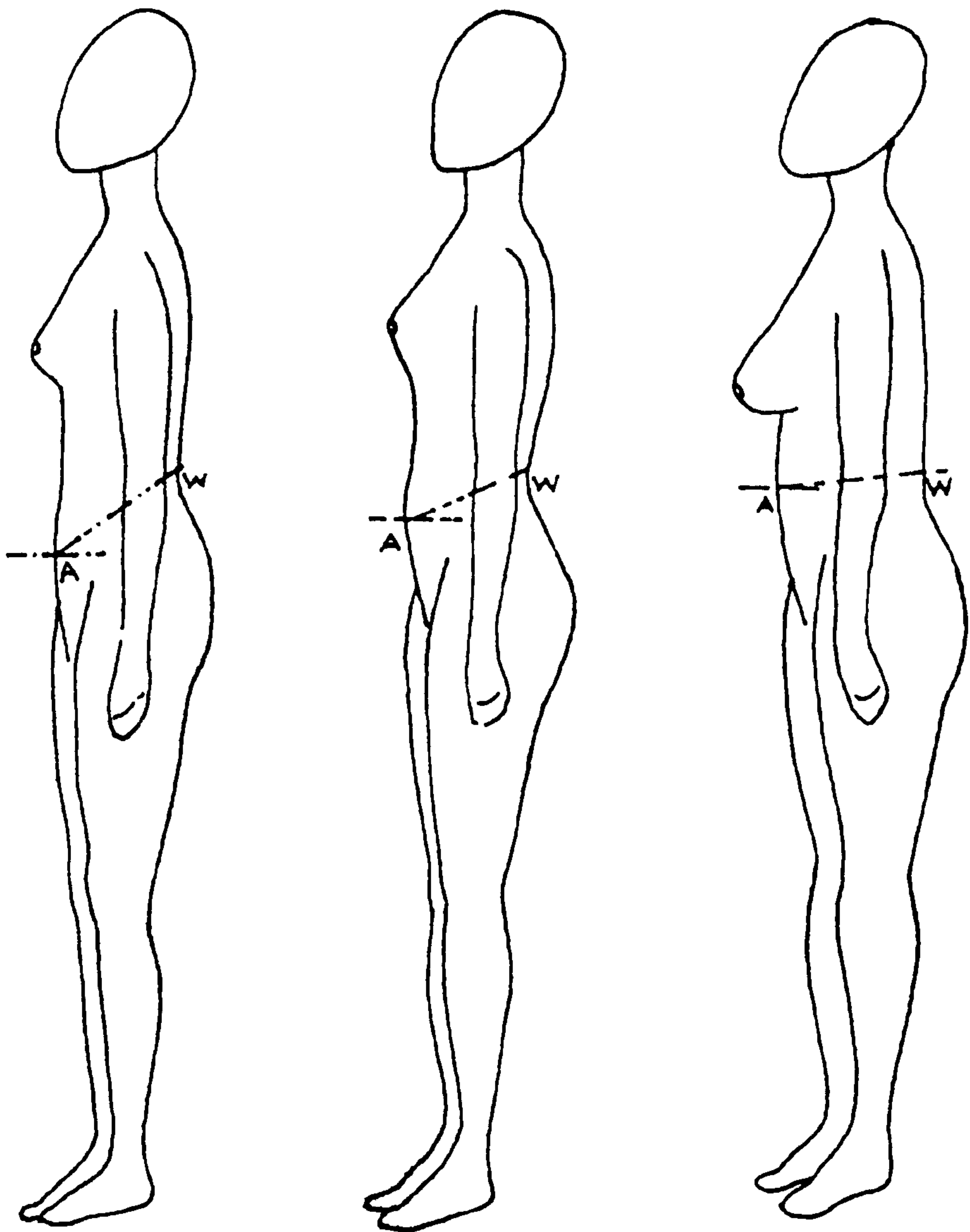


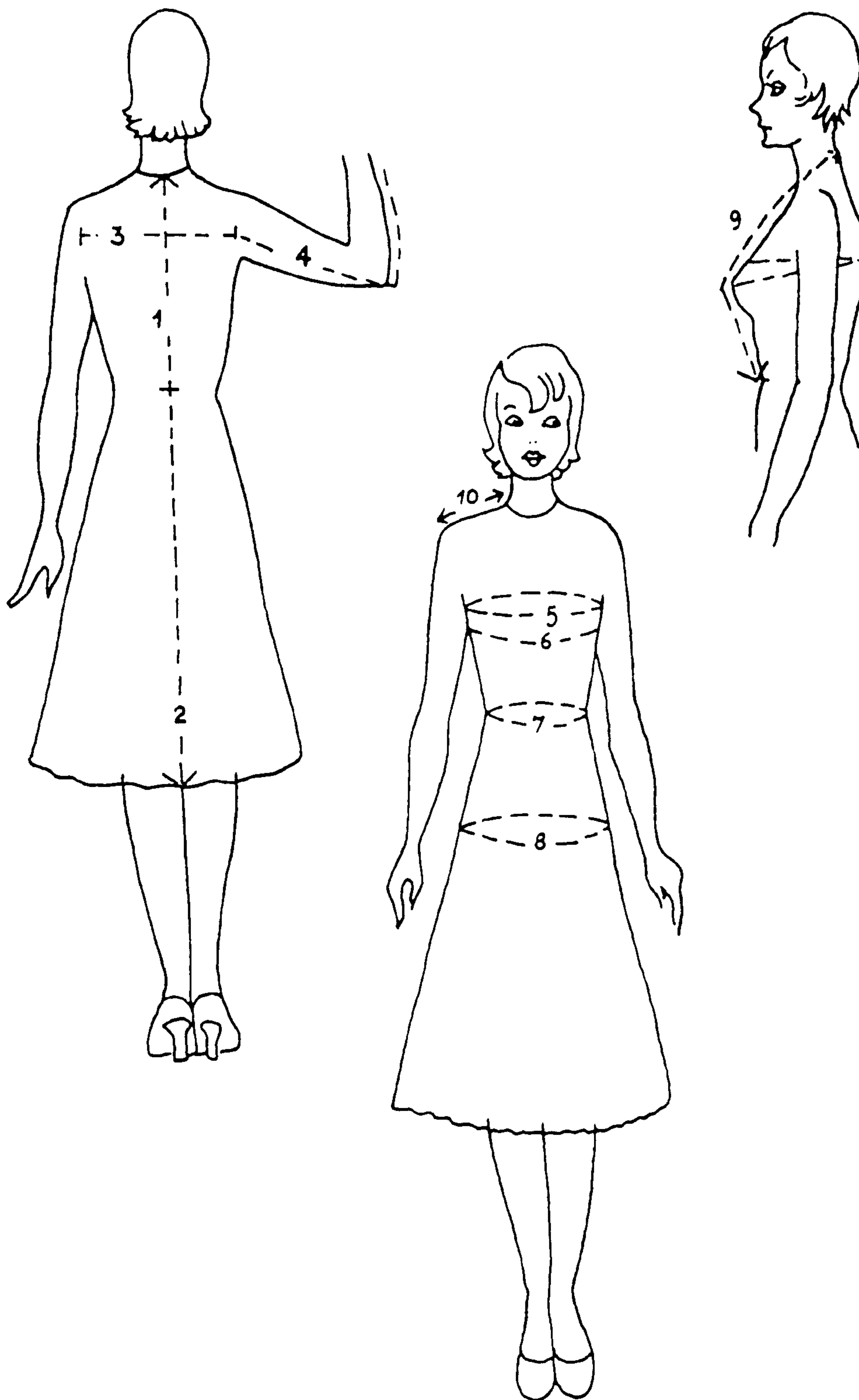
FIG. 12

Whife concludes that, there is obviously a great lack of correlation between girth and length dimensions and the actual shape of the female body. He concluded that in order to obtain garments which will accurately fit the human body, it is necessary to supplement the tape measurements with an intelligent interpretation of eye judgement of the figure shape of which the tape is not capable. This judgement is necessary to bridge the relationship between girth dimension and body shape.

Whife's conclusion about the error in obtaining a garment of accurate fit using a tape measure is obvious from all the examples already quoted. However, his opinion that good fitting garments need 'judgement' in addition to tape measurements, is not so obvious. Only by experience and skill, acquired by the traditional trial and error methods, can the necessary 'judgement' be obtained and a garment of good fit produced. Today, with the demand for an instant good fitting garment, and when the number of people with the necessary experience to deliver these well fitted garments are too few to satisfy the demands, an established scientific relationship between body shape and pattern shape is of fundamental importance.

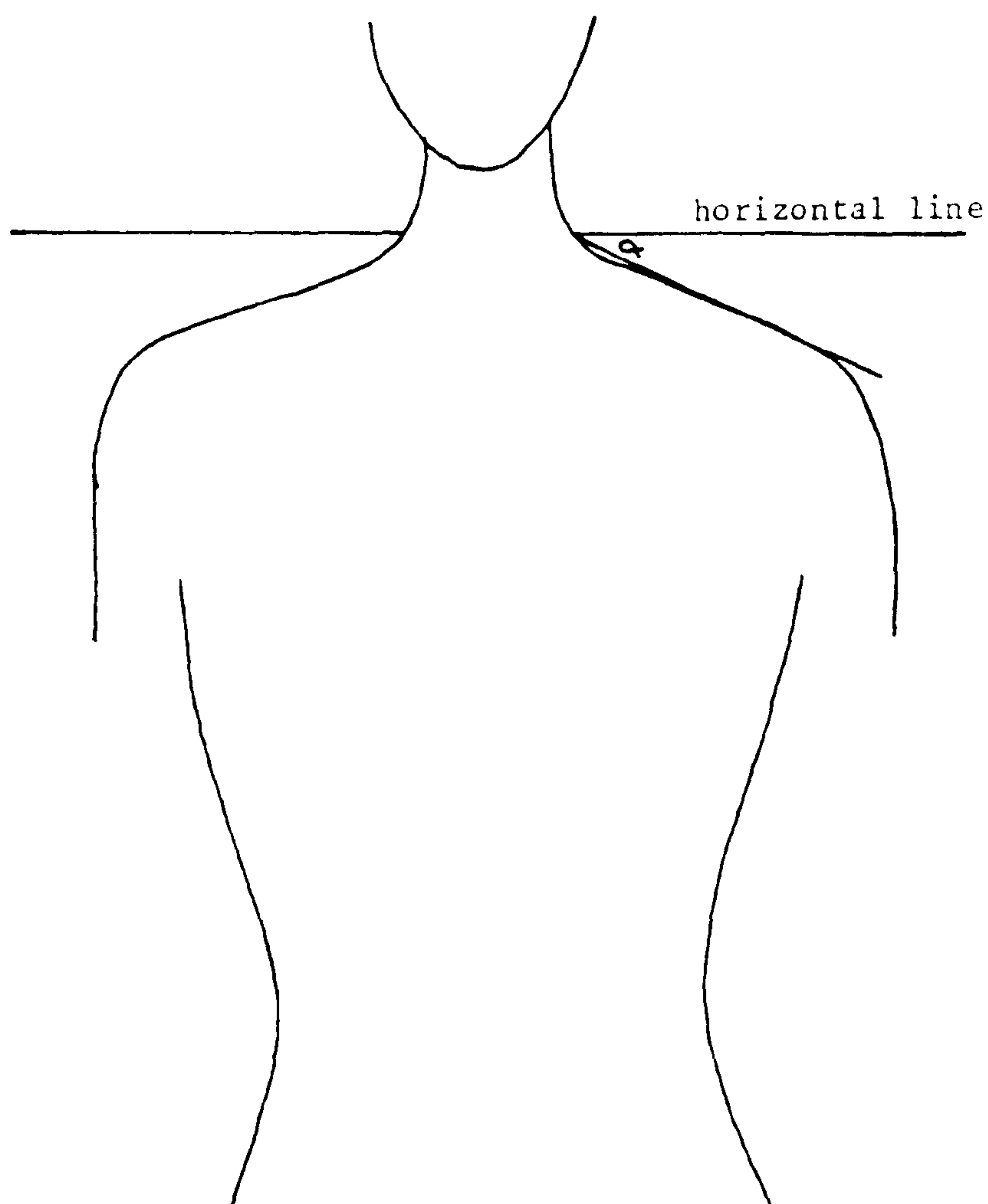
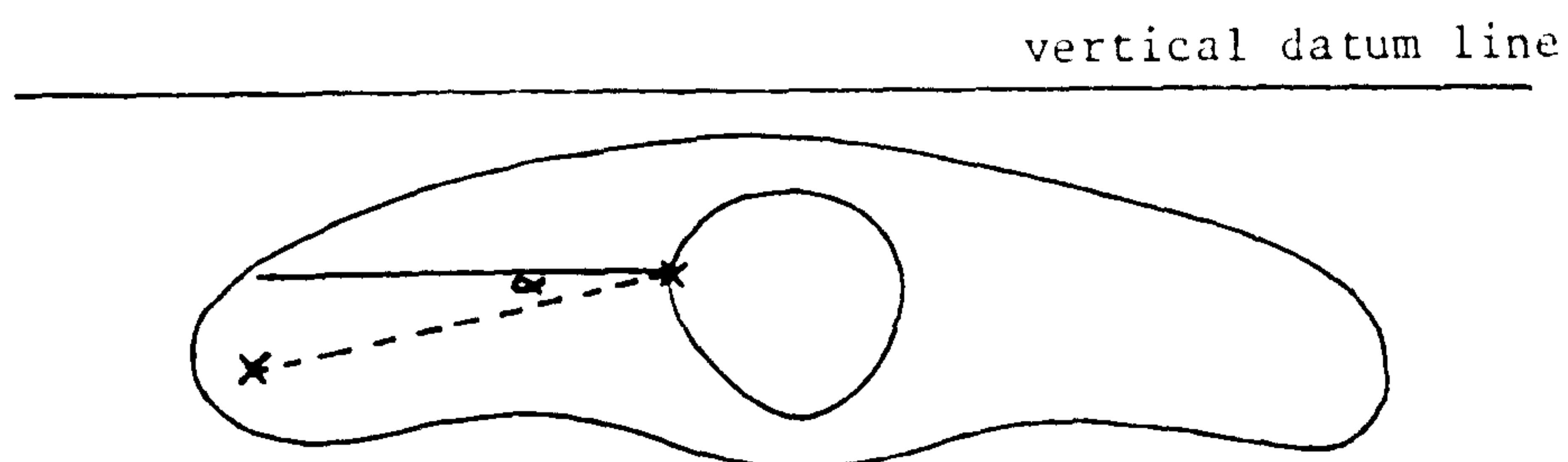
Further work on body shape determination and body fit was carried out by R. Hutchinson (12), who based his work on a life time's work as a tailor and cutter in the clothing industry. He maintained that the critical area of the body, as far as fit was concerned, was the shoulder area. He stated that if a manufacturer could rely on being able to produce garments which fit a figure perfectly between the neck and the horizontal line encircling the figure at the lowest level of the armhole, then the main fitting difficulties would be overcome. It is the complex nature of the shoulder area, as opposed to other body parts, which poses the problems of fit; and yet he showed that in spite of this, if a female person is measured for a garment, the normal measurements taken are those illustrated in Fig.13. Of these, the first eight are conventional measurements whereas no. 9 and 10 are optional. Only measurement no.10 relates to the shoulder area and this in no way indicates it's three dimensional characteristics. Hutchinson's main claim was that in order to obtain a satisfactory fit, the angle of the shoulder depression (i.e. the angle between the horizontal line and the shoulder line) must be established as well as the forward attitude of the shoulder (see Fig.14).

In order to measure these characteristics, a small survey was undertaken whereby forty four females divided into three age groups: 18 - 29, 30 - 44 and 45 - 60, were measured using a newly designed measuring frame (see Fig.15) which enabled the user to measure, in addition to all the usual measurement, the forward attitude and angle of depression of the shoulder.



TAKING MEASUREMENTS TO PRODUCE A FEMALE GARMENT

FIG. 13



ESTABLISHMENT OF SHOULDER DEPRESSION AND FORWARD ATTITUDE

FIG. 14

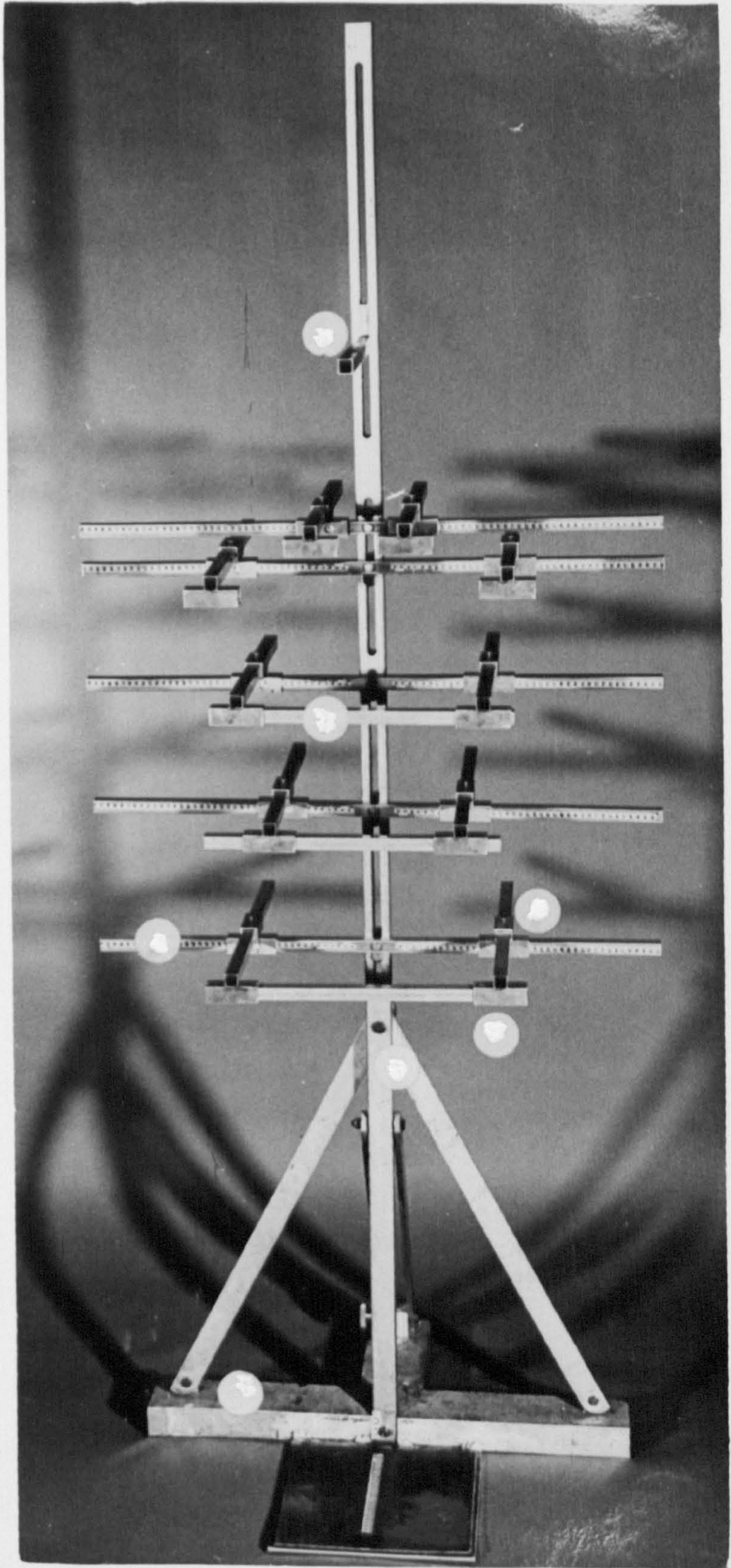


FIG. 15

Three main features came to light as a result of the investigation:

- (i) The shape of the body across the back in the horizontal plane is different for different age groups i.e. the curvature across the back increases as the age group increases.
- (ii) The determination of shoulder shape, in terms of the angle of depression was very important. Women vary quite considerably in this respect. Some have an angle of depression as high as 23.5° , others as low as 18° , where the average of all age groups was 21.5° .
- (iii) The shoulder shape in terms of the forward angle of women vary in this respect between 9° - 16° . It was found that although the forward angle of shoulder is not significantly affected by age, the roundness of the back is.

Apart from the above features, another major result came to light, that of the shape of the workroom stand. In addition to the forty four female figures, two of the standard workroom stands were measured. The results revealed that:

- (i) Both workroom stands have less curvature across the back than any of the female figures measured.
- (ii) As far as shoulder depression was concerned, it was revealed that one of the workroom stands fitted well the average figure obtained from the statistics gathered from the survey, whereas the other one had a higher shoulder angle than any of the women measured.

(iii) As so far as the forward placement of the shoulder was concerned, both workroom stands were measured 2° and 4° respectively, being very different from those of any of the women who had been measured.

In these respects, it was clear that neither of the workroom stands resembled the shape of the average woman's figure obtained from the forty four women who had been measured.

Others who have considered the effectiveness of the workroom stand have also commented on its difference from that of the normal human body. Cain (9) and Pepin (26), both stressed the fact that the workroom stand did not represent the normal figure, but allowed for ease allowance, and Brockman (27), like Hutchinson, found that there were considerable differences between garments constructed to fit different makes of workroom stand.

Analysing these results, it was apparent that a new concept in body shape determination was needed if a good and satisfactory fitted garment was to be achieved. In order to accommodate the work of the made-to-measure trade, a method for obtaining a better shaped pattern piece for individual figures was called for.

The method devised by Hutchinson was that of a 'moulding' technique which effectively produced a 'workroom stand' for each individual person and which could be transferred into two-dimensional pattern pieces.

These patterns were sufficiently different from those made according to traditional methods, to indicate that the shoulder depression and forward placement of the shoulder measured on live models significantly affected the pattern shapes required to obtain a satisfactory fit. Furthermore, trials with garments made from these new pattern shapes gave great wearer satisfaction as far as fit was concerned than garments made from traditional patterns.

The main result of Hutchinson's work therefore, was the fact that as far as good fitting garment production is concerned, the shoulder shape in the form of shoulder depression and forward placement, must be accurately allowed for before a satisfactorily fitted garment can be achieved. The work also revealed many incorrect assumptions currently used when measuring people for fit.

The perfectly fitted garment however, is one that not only fits on the shoulder, but all over the body. The only way therefore to arrive at a good and satisfactorily fitted garment is that of achieving a full body shape determination of all parts of the body in question and relating this information to the appropriate two dimensional pattern shapes which, when sewn together, with the insertion of darts, gives an accurate three dimensional model of the human figure.

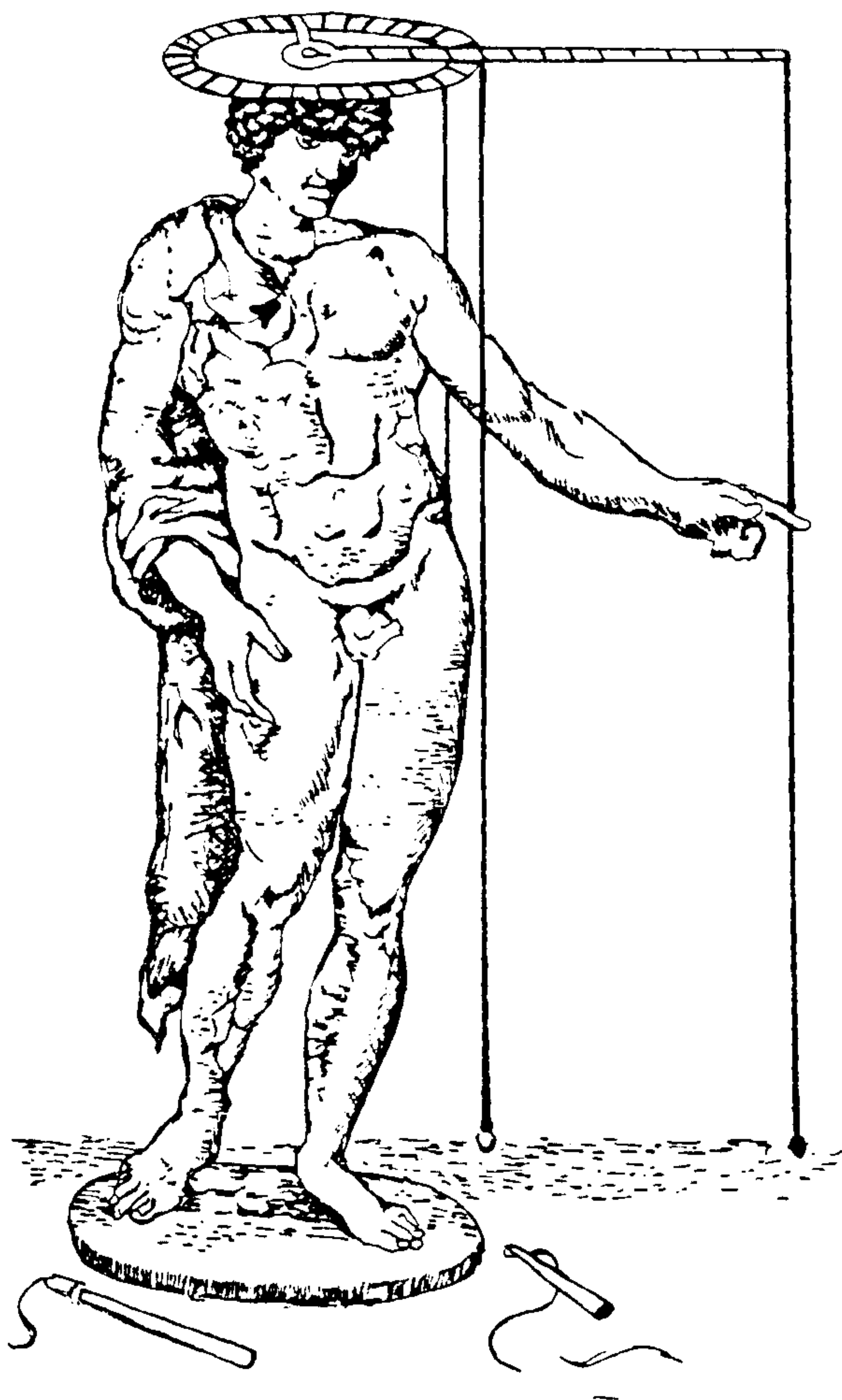
CHAPTER THREE

MEANS OF OBTAINING THREE-DIMENSIONAL BODY MEASUREMENTS

The measurement of size and shape of a human body has been practised for a long time, especially in such fields as anthropology, physiology and medicine.

It was found that as long ago as 1440 (28), sculptors were using a modified surveyor's disc to locate and record points on the body surface in three dimensions (see Fig. 16).

More recently, in 1916 Du Bois (29) developed a formula which was used to calculate surface area from the height and weight of people, and in the early 1950's, stereoscopic methods were developed in such fields as medicine and dentistry. In addition, anthropometric surveys have established data gathered from three-dimensional body measurements obtained using a wide range of sensors and apparatus, which were used to produce specially designed garments such as pressure suits, diving suits, etc. As previously described, in the garment making industry, despite the existence of data of body measurements, the three-dimensional characteristics of the human body are still assessed by trial and error methods with the aid of the tape measure, methods which can only give a general description of the three-dimensional nature of the particular human body rather than an accurate three-dimensional shape.



FIFTEENTH CENTURY MEASURING DEVICE TO LOCATE POINTS
IN THREE-DIMENSIONS

FIG. 16

Over the years, various methods have been established to measure the body in its three-dimensional form. The following methods have been used extensively in anthropometric studies and may be grouped as follows:

3.2.1 MONOPHOTOGRAMMETRIC

This method requires photographs of a subject to be taken from a number of different directions. From accurate measurements extracted from these photographs, it is possible to determine the three-dimensional body form. Usually, the subject stands on a turntable which is oriented in such a way as to allow the taking of photographs of each side of the subject without the subject changing his pose. Alternatively, by using a special photometric camera and with the aid of mirrors, four images may be produced from a single exposure thus eliminating the need for a turntable.

The body volume and surface area can be obtained by either assuming the shape of the horizontal cross-sections of various parts of the body to be an ellipse, where its perimeter can be calculated by measuring their axis on the photographs (30), or by approximating various body parts to known geometrical shapes which can be used to calculate the results required (31).

The basic principle of stereophotogrammetry is exactly the same as that of binocular vision. If two stereophotographs of an object are placed in such a way so that the left eye sees the left photograph and the right eye sees the right photograph in proper relation, the perception of depth can be seen as clear as if the object were seen directly.

The stereophotogrammetric methods can be sub-divided into two methods according to how the photographs are analysed and used.

In the first method, the photographs are used as a basis for plotting a contour map from which measurements can be extracted. Hertzberg and others (32) presented a contour map of a male subject calculated from the front, back and side view; using this contour map, profiles or cross-sections between any two known points on the map, which can be either surface areas or complete circumferences of any section needed, were plotted (see Fig. 17).

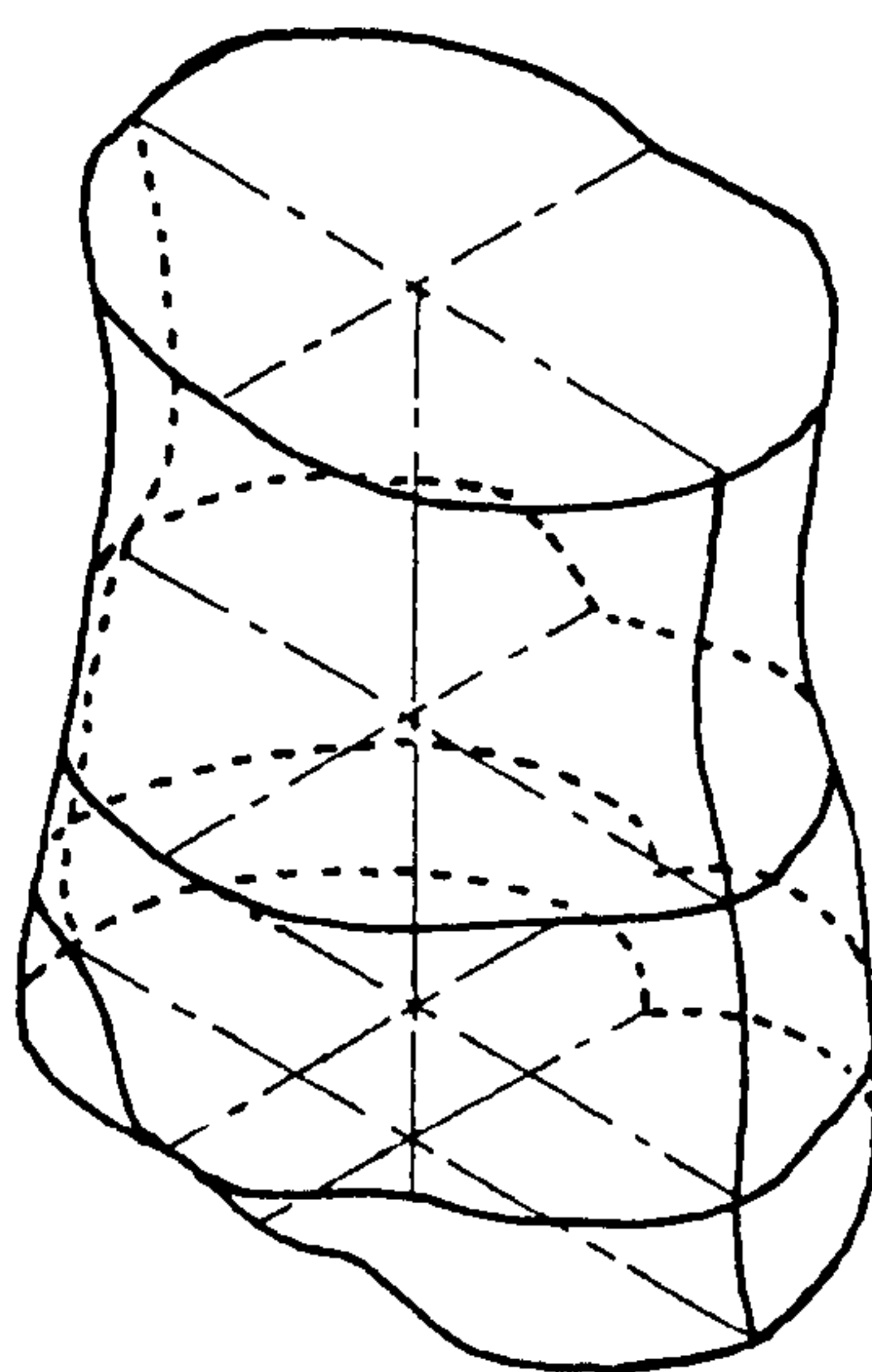


FIG. 17

In the second method, co-ordinates measured on the photographs themselves are recorded, thus eliminating the need for a plotted map. Weissman (33) presented a programme which can read these co-ordinates off the photographs and calculate the total surface area of the body and its volume.

3.2.3 Conclusion

The above methods, although regarded as the "most promising means of obtaining body measurements" (33) and as the "only means of providing simultaneously dimension and form of all features of the human body" (32), cannot be recommended for use for the determination of body shape for clothing purposes because they are slow, extremely time consuming and require a highly experienced work-force to interpret the information and analyse the results. Furthermore, most of these methods are used primarily for the gathering of anthropometric data for determining either body surface area or body volume and do not lead directly to body shape determination.

Almost the only attempt until recently to apply the methods used to gather anthropometric data to help in producing patterns for clothing purposes, is the photometric method.

The photometric method which was described as a method for obtaining made-to-measure garments (34) involved taking photographs of a subject's image and by analysing it, producing a pattern to fit the subject. A special room was used which contained of a photometric camera, specially designed lighting and a series of mirrors placed in fixed positions around the room, which returned the subject's image to the camera from four different angles - front, profile, back and overhead. The photometric image was then projected onto a screen in life size, thus enabling the pattern maker to transcribe from the screen to the pattern not only the traditional measurement recorded on the photograph, but also any other irregularities of the subject's figure.

Although this method might produce a satisfactory result, there is no evidence to suggest that it is used widely in any sector of the clothing industry and as such, no evidence could have been gathered to evaluate its success.

Another attempt to measure the three dimensional characteristics of the human body for clothing purposes, was an attempt made by J. Neath to record the body measurements electronically.

Neath developed an electronic measuring device which consisted of a number of probes which located the position of various parts in the shoulder area and tape measures which were designed to automatically read distances around various parts of the body. (See Fig.18) These measurements and positions were fed to a computer and were available in printed form. Neath used this information, along with a basic pattern of his own design, to modify the shape of the basic pattern produced by traditional methods, to produce a pattern to fit the body being measured.

This device was tested by two large tailoring organisations, in which a number of employees were measured on the apparatus and patterns were cut for each person. The patterns were then tested for fit and were compared against the pattern produced by traditional methods. Both firms found the method unsuitable for use because the patterns produced were inferior in the degree of fit obtained by the traditional patterns and for this reason, the method has not been used commercially for garment production. However, this device was used in the recent WIRA survey.

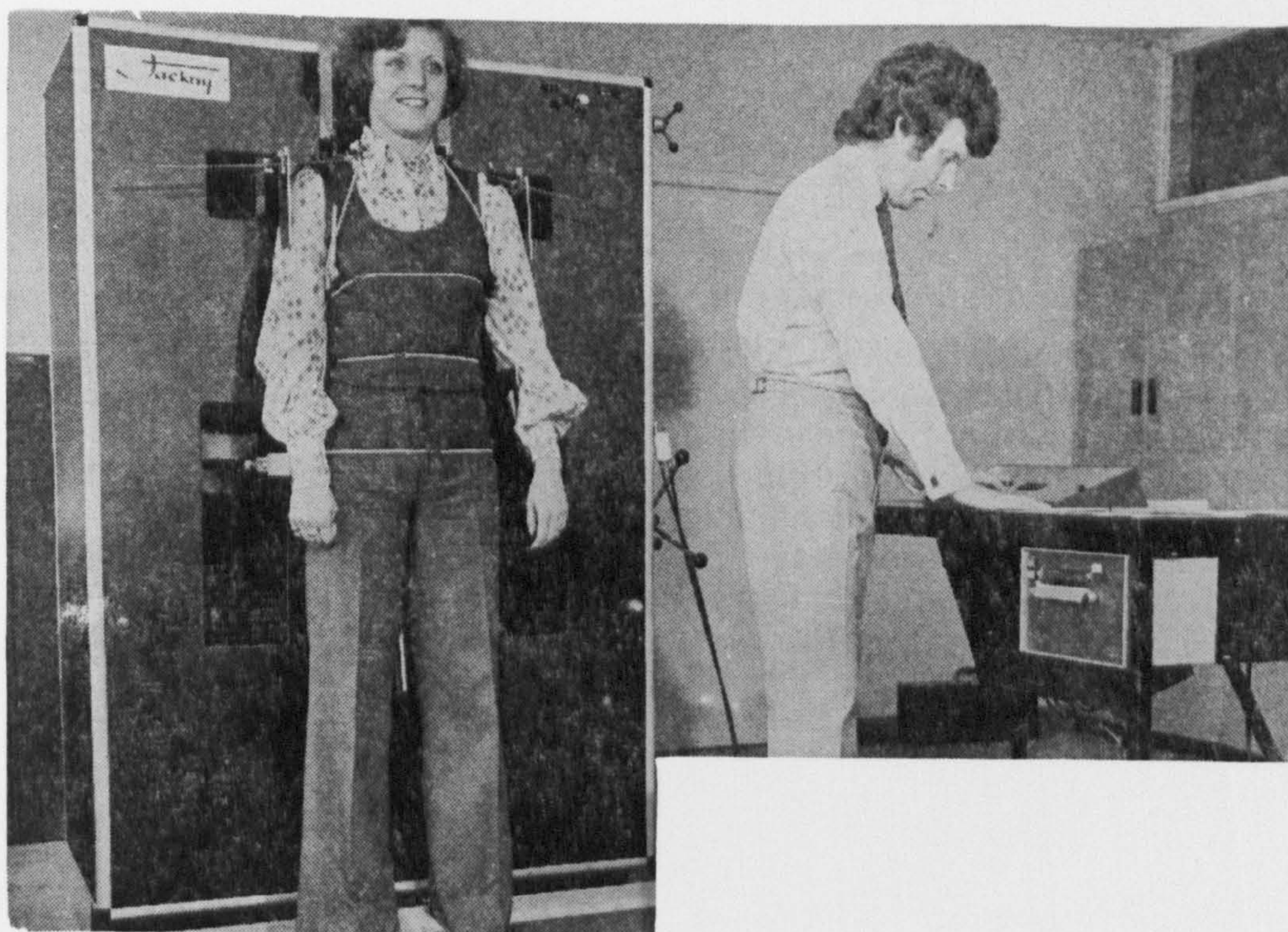


FIG. 18

As previously described (see section 3.2.2), the moulding method was developed by R. Hutchinson (12) as a new approach to solve the problem of body shape determination.

This method effectively produced a 'workroom stand' for each individual person which could be transferred into two-dimensional pattern pieces. The method involved the use of a polyethelene foam sheeting material which was found to provide the best material from which to make a mould of a human body. One of the advantages which causes polyethelene sheeting to be chosen was it's ability to be moulded at temperatures as low as 110°C.

The material was placed in a preheated oven, thermostatically controlled at 140°C, for one minute, which has been found to be sufficient to make the polyethelene foam sheeting suitable for use. The warm foam sheeting was then taken from the oven and placed on the subject's body for thirty seconds. The material was then removed from the body and it was found that it effectively retained the shape of the subject. This 'shell' thus produced, was then cut and by insertion of darts in places on the 'shell', transferred into a flat two-dimensional body pattern which could be used as the block pattern for the individual subject.

CHAPTER FOUR

DISCUSSIONS OF GARMENT FIT

The need for a better fit in garments has been recognised by both industry and customers for a long time. It has been shown (35) that fit is the single most important element in the appeal and saleability of a garment, more important than style features, fabric type, colour, price etc. Despite this, the principles of fit and the understanding of which factors contribute to a good fitting garment are not clearly understood by pattern makers working in the industry, including those who have a good understanding of clothing construction.

A great many factors influence the fit of a garment and because of its abstract nature, fit has been defined in many ways. This reflects the lack of agreement within the industry on the features that are responsible for a good fit.

Generally, fit can be defined as the "ability to be the right shape and size" (36). However, for the purpose of garment construction, a well fitted garment can be described as one that conformed to the human body and has adequate ease for movement, has no wrinkles and has been cut and manipulated in such a way that it appears to be part of the wearer (37).

Erwin (38) however, probably reflects the opinion of practical dressmakers when stating that fit is basically a combination of five factors which are related directly to the ability to produce a perfect fitted garment, namely: ease, line, grain, balance and set. These five factors are described in more detail overleaf.

- (i) Ease is referred to as the difference between body and finished garment measurements. The amount of ease provided in a garment varies in importance from season to season, as fashion evolves and tastes change.
- (ii) Line, in this context, refers to the fact that the seam of the garment should appear to match the silhouette line. Thus, a vertical seam should appear to be perpendicular to the floor, a centre seam should occur on the centre of the body, a side seam should appear to divide the body in half vertically and the horizontal seams should appear to be parallel to the floor.
- (iii) The direction of the grain of the fabric is considered to be of great importance in achieving a garment of good appearance and fit. The direction of the grain of the fabric is largely determined by the direction and manner of placement of the pattern pieces during lay marking. To achieve the correct direction of the grain in a garment, the patterns have to be laid to ensure that the lengthwise grain will be parallel to the vertical axis of the pattern and hence will appear perpendicular to the floor on the finished garment.

The crosswise grain should be parallel to the horizontal axis of the body and hence parallel to the floor at bust and hip lines on the finished garment.
- (iv) Balance is described as the relationship of the different parts of a garment to each other and the way in which they hang from the wearer's body. For the garment or part of it to appear in balance, it must fall or extend away from the body at the same

distance front to back or side to side.

- (v) Set is referred to as the absence of wrinkles in the garment when worn on the body.

Posture, as well as body build, has a direct influence on the fit of a garment and according to Cain (9) fit was directly related to the anatomy of the human body. It is evident that most of the fitting problems encountered by the pattern makers are created by the bulges of the human body.

As already mentioned, Hutchinson (12) indicated that the most important factor which has to be taken into consideration when producing a garment of good fit is the shaping of the garment over the upper part of the body - namely the shoulder area. Both Minot (39) and Eddy (40) came to the same conclusion, pointing out that the slope of the shoulder is one of the most critical factors in determining body fit, and that unless the pattern resembles the shape of the shoulder slope correctly, a poor fitted garment is inevitable.

Although the appreciation that fit of a garment is a critical feature of the effectiveness of the appearance of the garment, and although the work described above indicates that workers have attempted to rationalise the problem of fit, because of its complexities, and the effect that design and fashion has upon it, no attempt to quantitatively compare the fit of garments has been reported in the published literature.

It is clear from the above discussion that garment fit is a complex property which is affected by fashion and style, in addition to such quantitative features is the fact that a garment hangs well from the body and conforms accurately to the shape and size of the wearer. To achieve the latter part of these requirements it is obvious, that the patterns from which the garment is cut, must be of the correct size and shape.

If pattern makers used the knowledge of anatomy and anthropometry to achieve the correct relationship between pattern and body shape, it should be possible to produce patterns that give a good fit to the body for which they are intended. In practice, however, the pattern makers working in the industry are lacking in this knowledge and usually base their pattern construction knowledge on rules that they have absorbed from various pattern experts with whom they have been associated; this knowledge having been established by the trial and error method which sometimes produces the right effect, but very often do not. The production of a garment of poor fit is therefore inevitable.

There are three types of patterns commonly known to be used in the production of garments which may be defined as follows:

- (i) The first one can be referred to as a 'skin pattern' - the pattern produced on the basis of the measurements taken directly from the body. The 'skin pattern' does not include either ease or seam allowances or any style features and is such that if the patterns were placed on the body, they would give a skin fit garment.

- (ii) The second type which is known as a 'block pattern' is a 'skin pattern' with the addition of ease, allowing for movement and the comfort of the wearer.
- (iii) The third type is the one referred to as a 'production pattern' which is the 'block pattern' with the addition of style features and seam allowances.

It is clear from the above definitions that since the block and production patterns are developed from the skin pattern, if a well-shaped finished garment is required, it is essential that the skin pattern be an accurate resemblance of the body shape.

A number of studies however, (39, 40, 41, 42) which were carried out on size and shape of block patterns, revealed that patterns from different pattern manufacturers varied in fit due mostly to lack of relationship between pattern shape and body shape. Amongst these Sieman(41) who compared five basic patterns from five different manufacturers and was supported by Disney (42) who made a similar study of her own.

It is clear that commercially, there are considerable differences of opinion between the various individual garment producers as to the precise and accurate patterns required to obtain garments which will accurately fit the human body.

This degree of disagreement which exists in a traditional industry which has been producing garments for generations, obviously reflects the difficulty of assessing the fit of a garment accurately and quantitatively.

PART B

THE REQUIREMENTS, DESIGN AND DEVELOPMENT OF A
PRACTICAL METHOD RELATING BODY AND PATTERN SHAPES

CHAPTER FIVE

INTRODUCTION

The forgoing chapters reveal that current problems in achieving good fitting garments are caused by the following factors.

- (i) The unsatisfactory nature of the measurements obtained from measuring the human body by the traditional methods of measuring the poor relationship between body and pattern shape which resulted from these measurements.
- (ii) The association of the process of garment production with the present design of the workroom stand which according to Hutchinson (12) and others does not resemble the human body accurately.
- (iii) The fact that modern methods of garment production require the garment to be engineered without any spare or extra fabric for fitting purposes,
- (iv) The fact that the traditional methods of body shape determination are far from accurate. However, the need for better fitting garments to satisfy a demand for higher standards of fitting quality, suggests that a scientific investigation into the problem of achieving a two-dimensional block pattern which accurately reflects the three-dimensional nature of the human body, could well be of extreme significance to the clothing and tailoring trades.

In order to carry out that investigation which was accepted as the topic for this thesis, a detailed analysis of the current method of producing patterns and the future trend were essential. In addition, it was important to select the areas of investigation and their priorities.

The following are the elements which were selected as the most important ones if a well fitted garment is to be obtained.

- (i) To design and build a reliable device for measuring the three-dimensional measurements of the human body.
- (ii) To establish accurate relationships between the three-dimensional co-ordinates and the two-dimensional block pattern.

- (iii) To obtain from these relationships a garment outline of accurate three dimensional fit.
- (iv) To propose methods for applying these established relationships commercially for the clothing and tailoring trades.

Each of the above elements has been investigated in the current work, and are described in the following chapters.

CHAPTER SIX

THEORETICAL CONSIDERATIONS

M.D. Erwin (38) has stated that "the human body is made up of many subtle curves" of which the major ones might be referred to as "bulges", which include the bust point, the end of the shoulder, the tip of the shoulder blade, the elbow, the abdomen, the side hip and the back hip. Erwin also suggested that in order to make a flat fabric fit smoothly over a bulge, a dart is required for each of the major bulges.

In addition to these features stressed by Erwin, it is obvious that the shape of the body varies in dimension along its length and in order to achieve a garment of good fit, this variation should be allowed for. Wherever there is a difference between two adjoining dimensions (i.e. hips and waist, bust and waist, lower shoulder blade and waist, etc) some form of shaping is necessary.

The degree of shaping required is obviously dependent on the difference in dimensions of the adjoining parts of the body. If the bulge is large and the diameter differences are large, a greater degree of shaping will be required to accommodate these differences. Hence, shape control always represents a relationship whereby the greater the difference is, the greater the need for control and the larger the amount of control needed.

6.2 THE THEORY OF SHAPE CONTROL

6.2.1 Introduction to dart control

Garment manufacture consists essentially of converting a two dimensional i.e. flat fabric, into a garment which will accurately fit, or hang well, when worn on a three-dimensional body. The conversion of a flat pattern into a three-dimensional garment is achieved primarily by the insertion of darts, which are stitched folds that usually taper into a point. A dart however, need not be stitched to a point, it may be left incomplete as a tuck, leaving some soft fullness; it may be held by ease, gatherings, folds, or may be stitched in curves. (See Fig. 19).

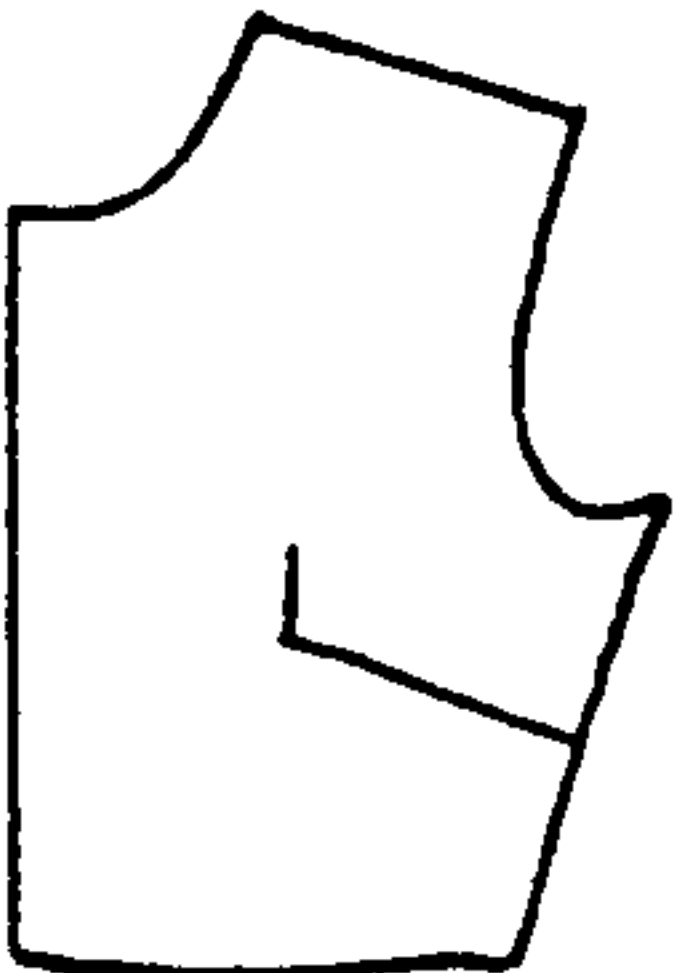
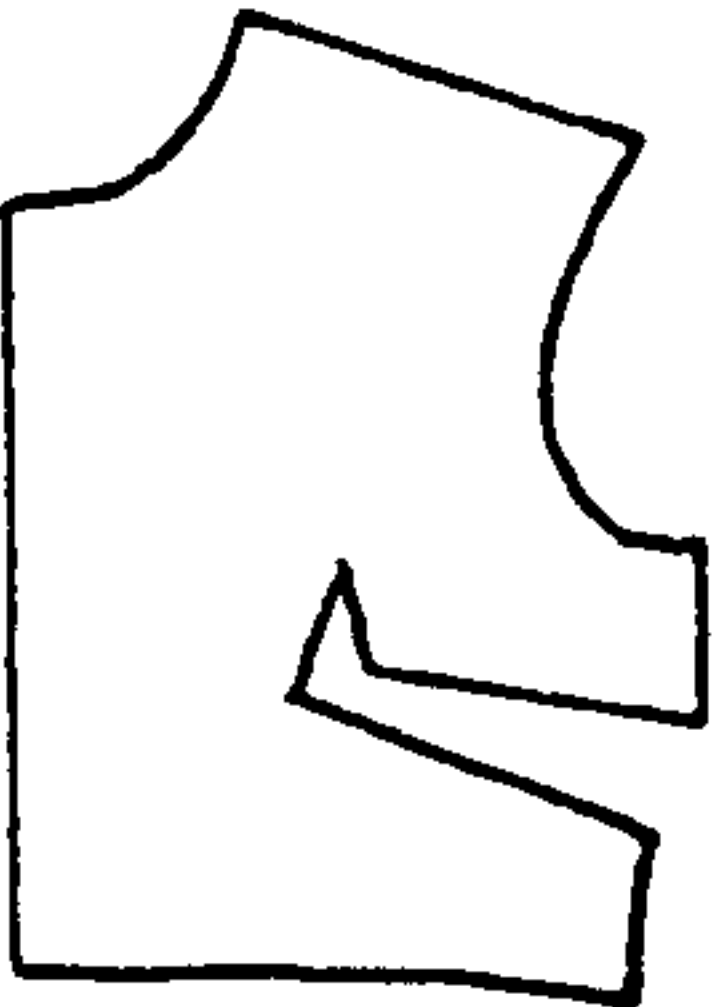
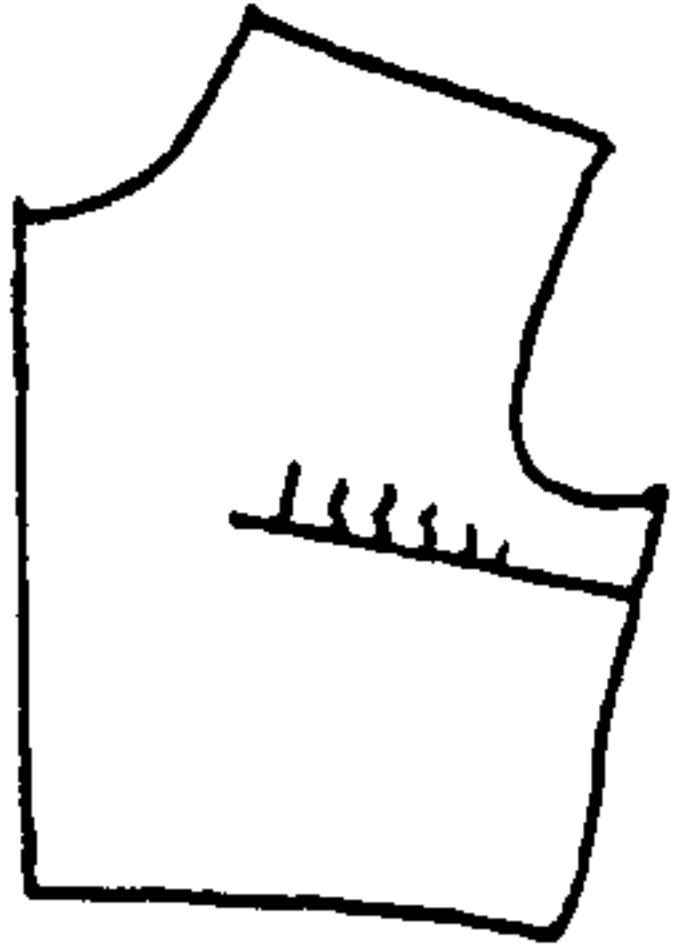
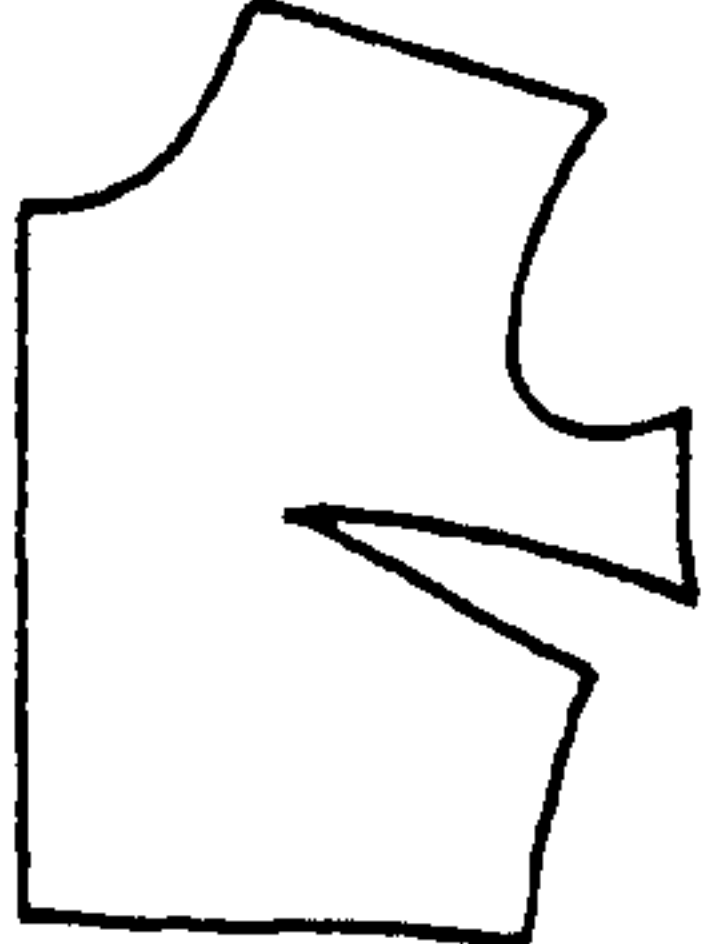

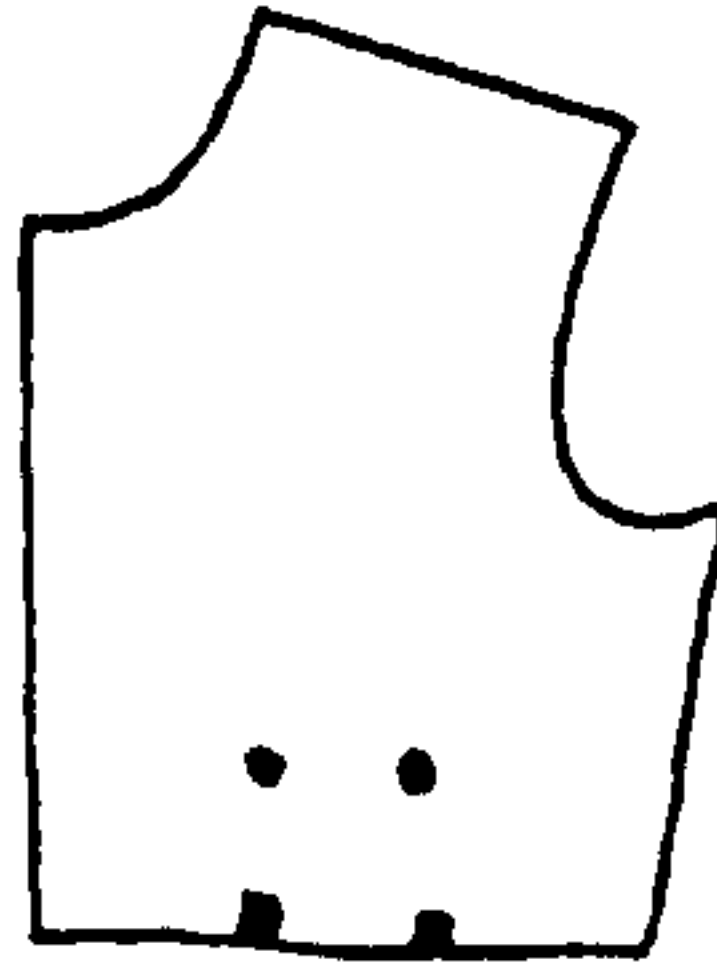
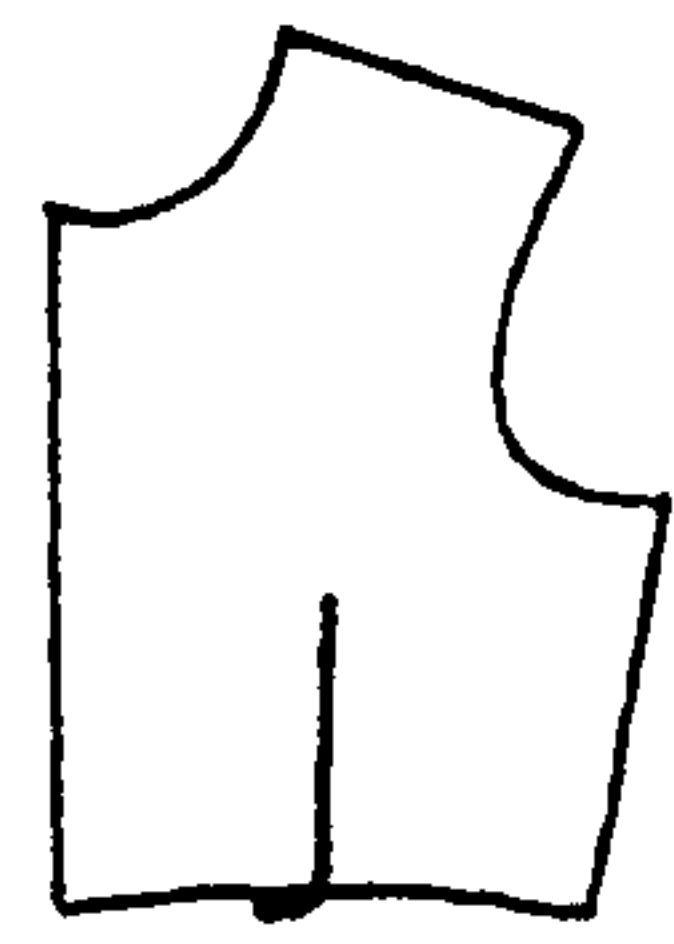
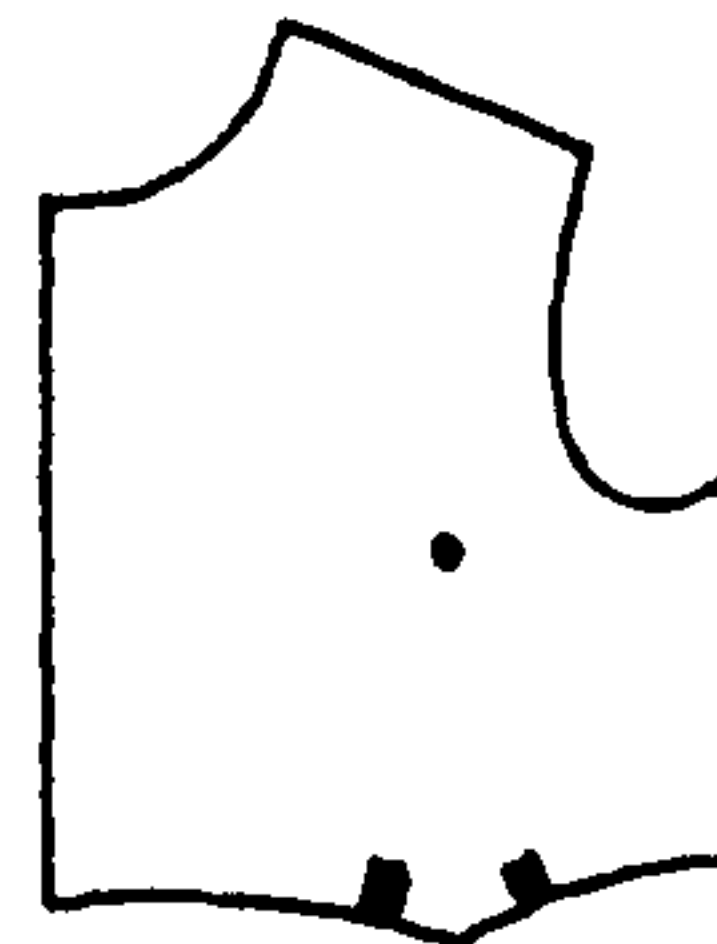
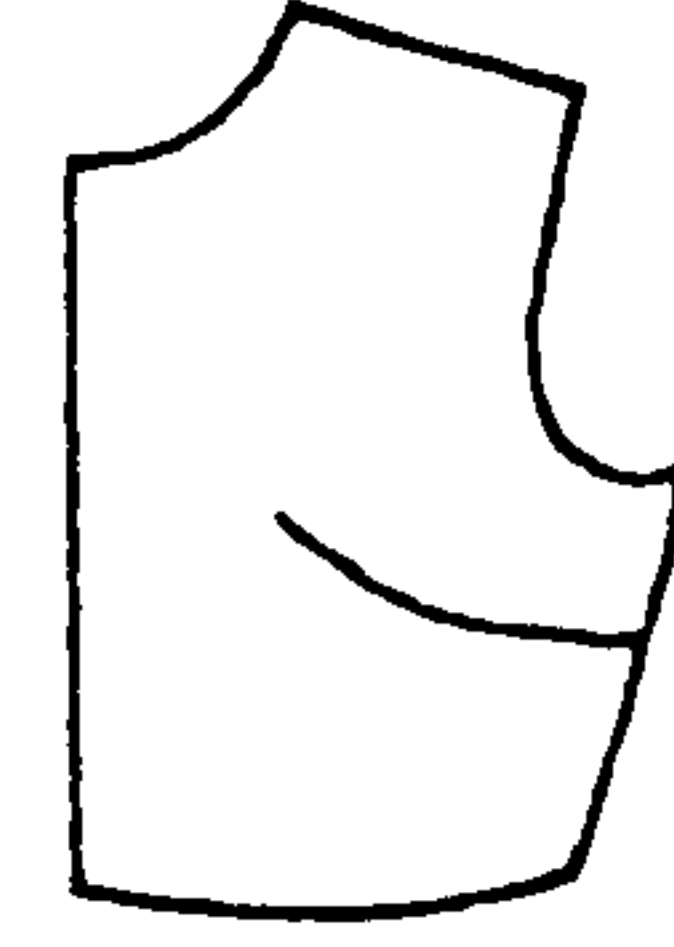

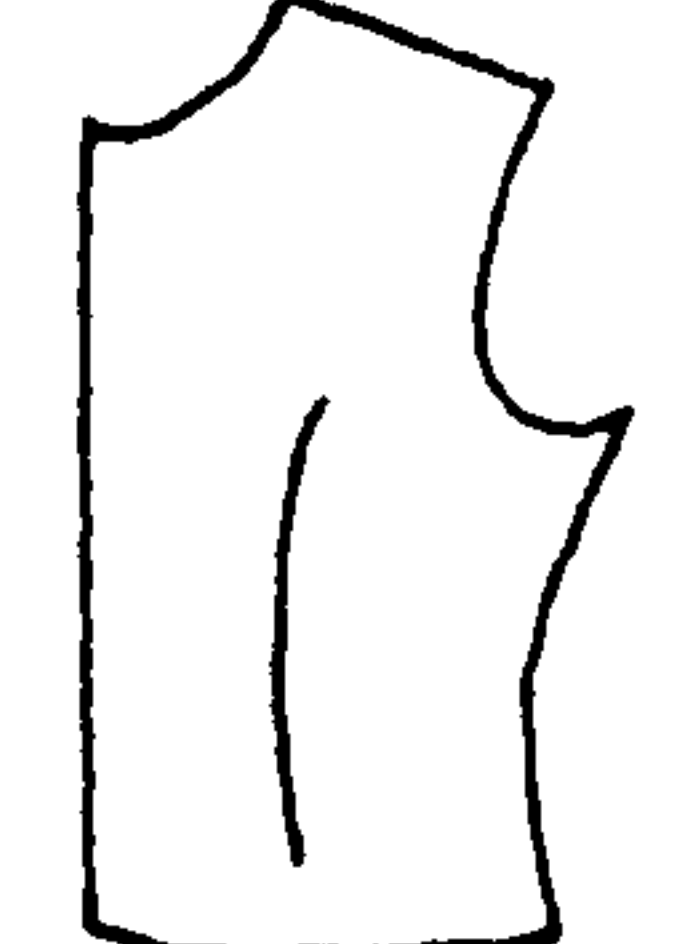
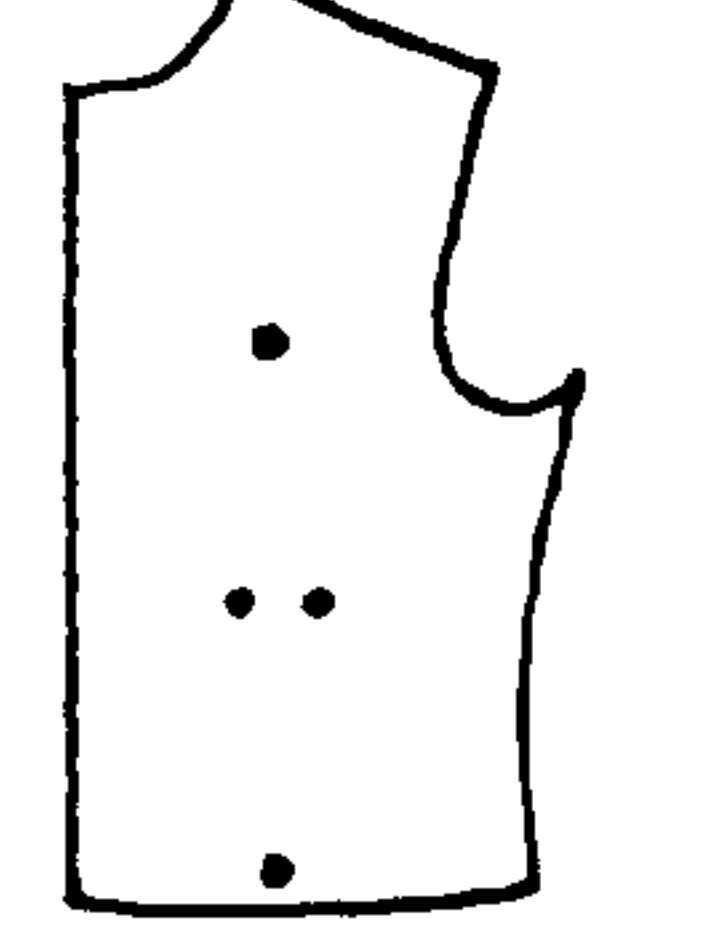
Darts, which are part of a wider system of shaping, are not always an obvious part of the garment construction in that they are often hidden in the seams on the outline of the body, such as the sideseam, shoulder seam etc. (See Fig. 20).

6.2.2 The principle of achieving three-dimensional shape by the use of a dart

The principle of dart insertion in order to achieve a three-dimensional shape from a flat piece of fabric is most simply indicated by the example shown in Fig. 21.

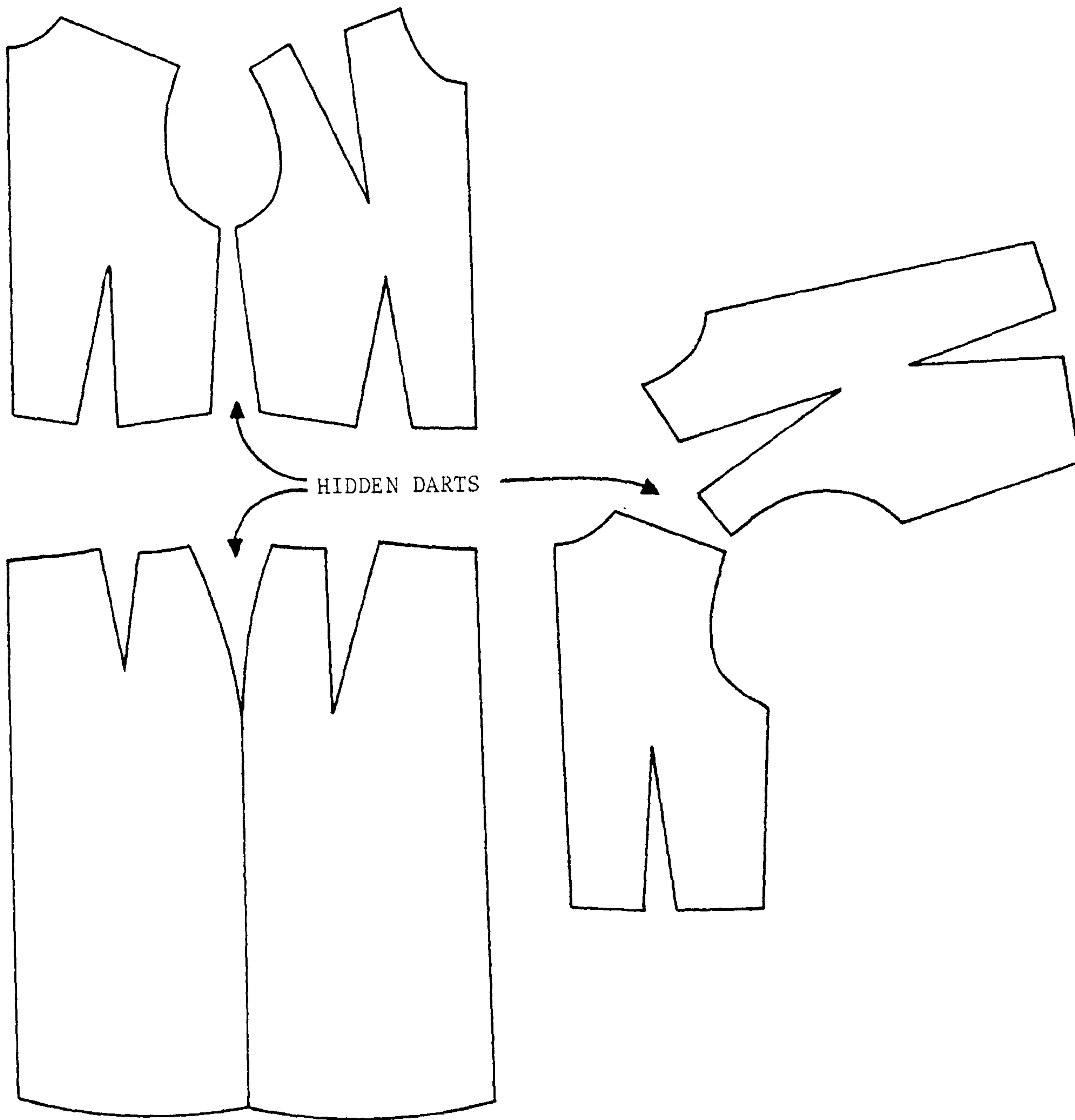
When a triangular section is cut from a circular two-dimensional flat piece of fabric (see Fig. 21a), the resultant fabric when the two edges are joined together, forms a three-dimensional conical shape (see Fig. 21b).

The apex angle of the cone obtained in this way is obviously determined by the size of the triangular section cut from the circular piece of fabric (i.e. the bigger the triangular section the higher the cone).

DART DESCRIPTION	DART SHAPES	DART OPEN
BIBA DART		
GATHERED DART		
DART TUCK		
WEDGE DART		
CURVED DART		
CONTOUR DART		

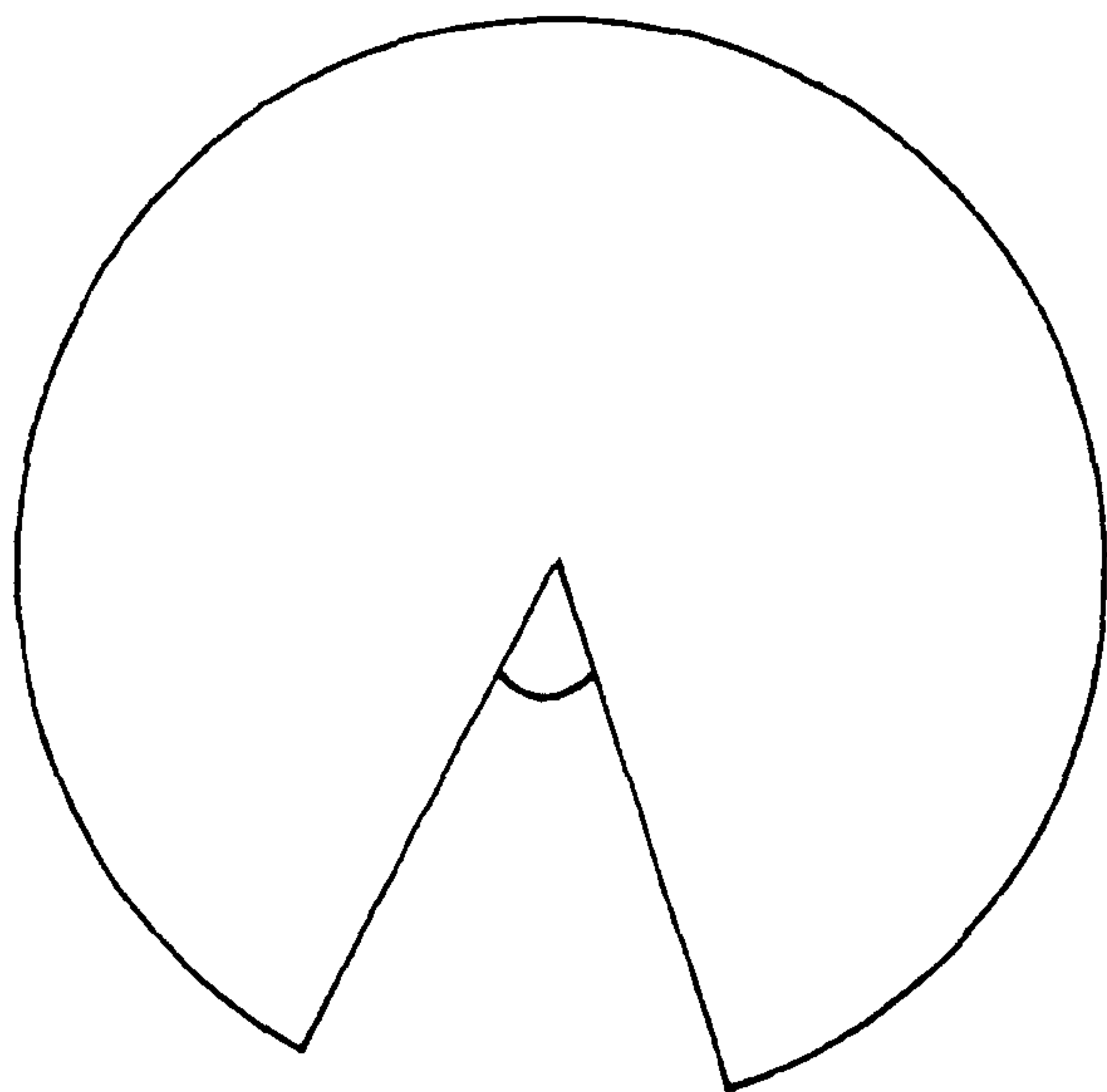
TYPES OF DARTS

FIG. 19

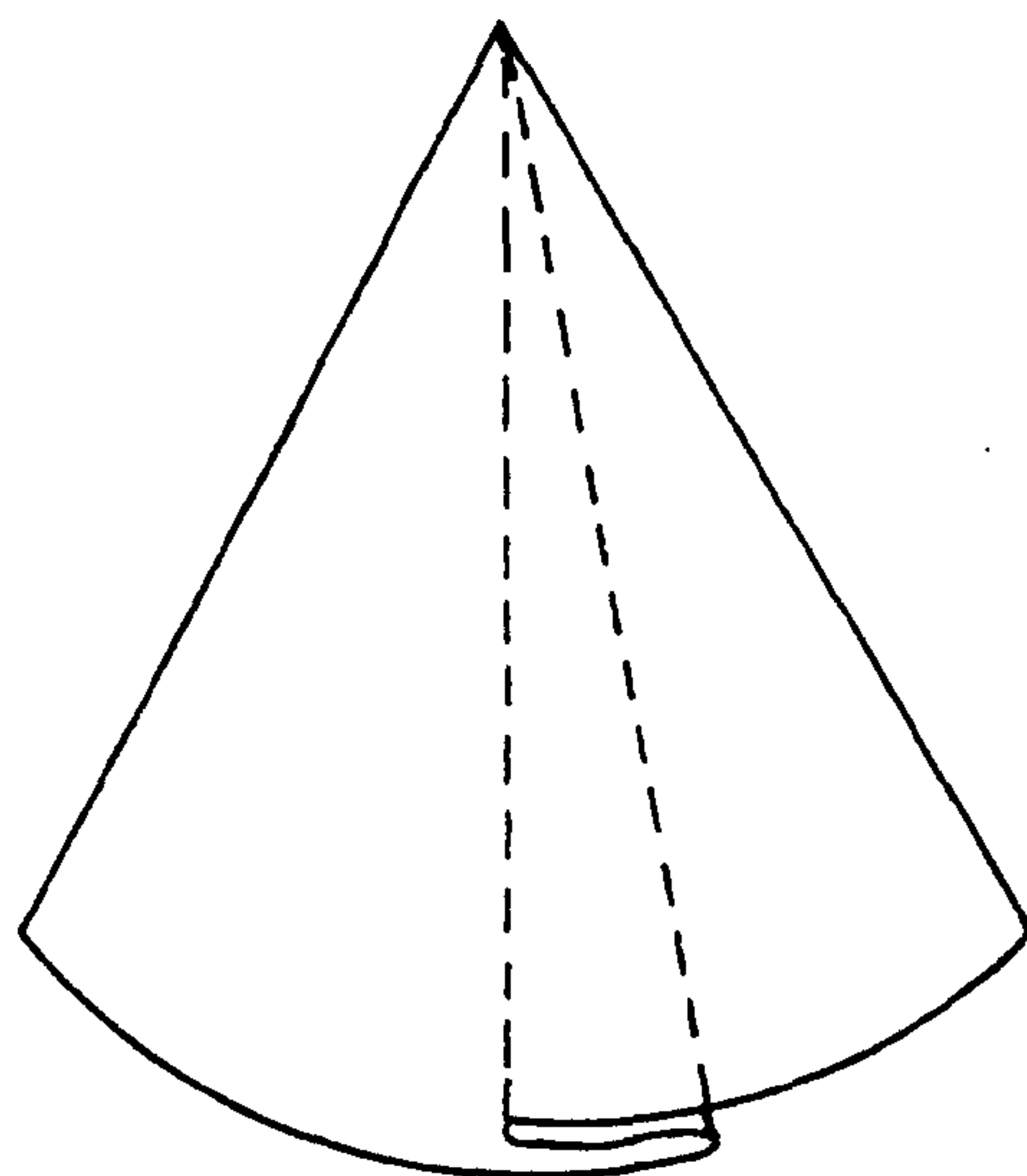


LOCATION OF HIDDEN DARTS

FIG. 20



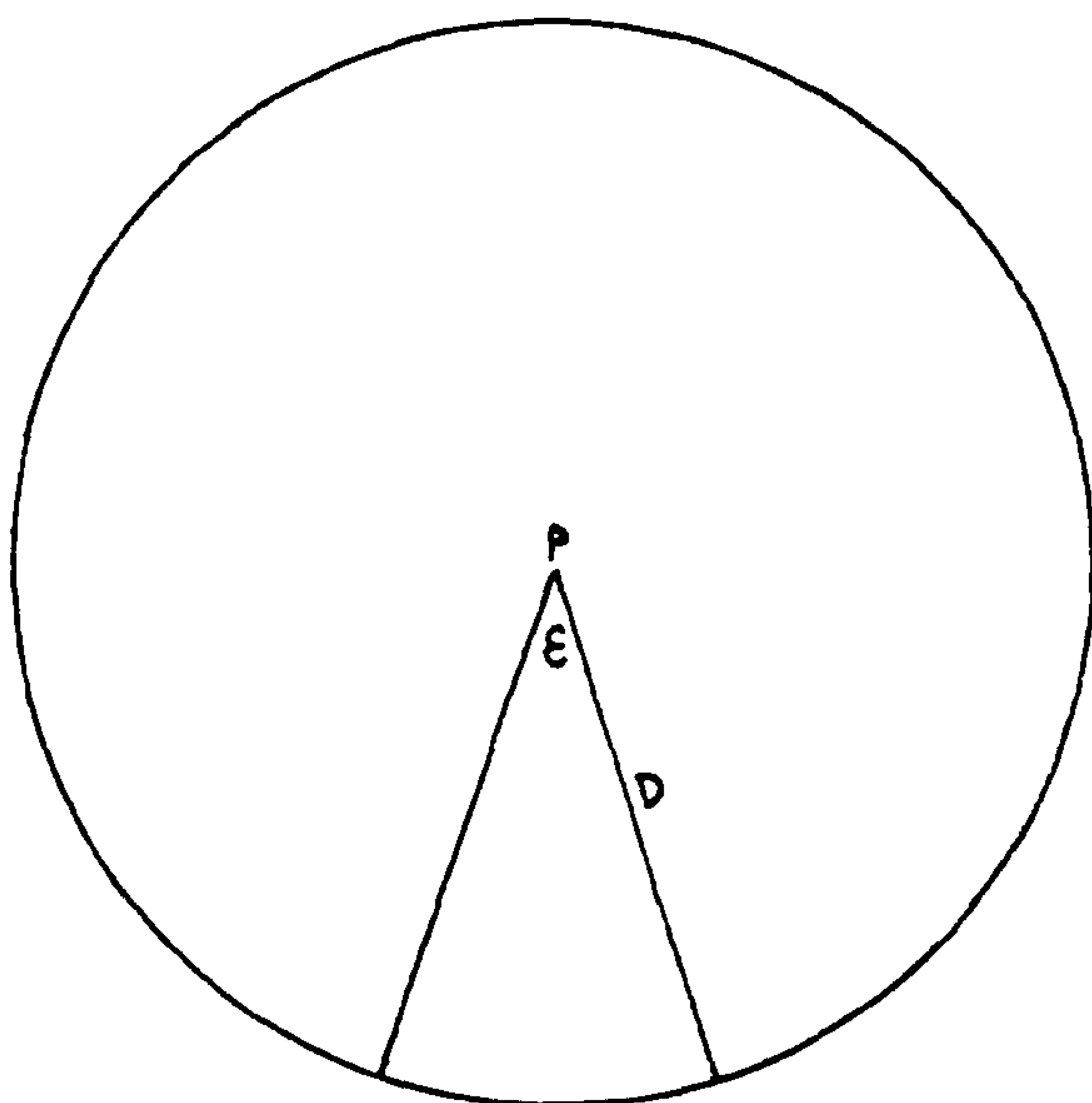
A



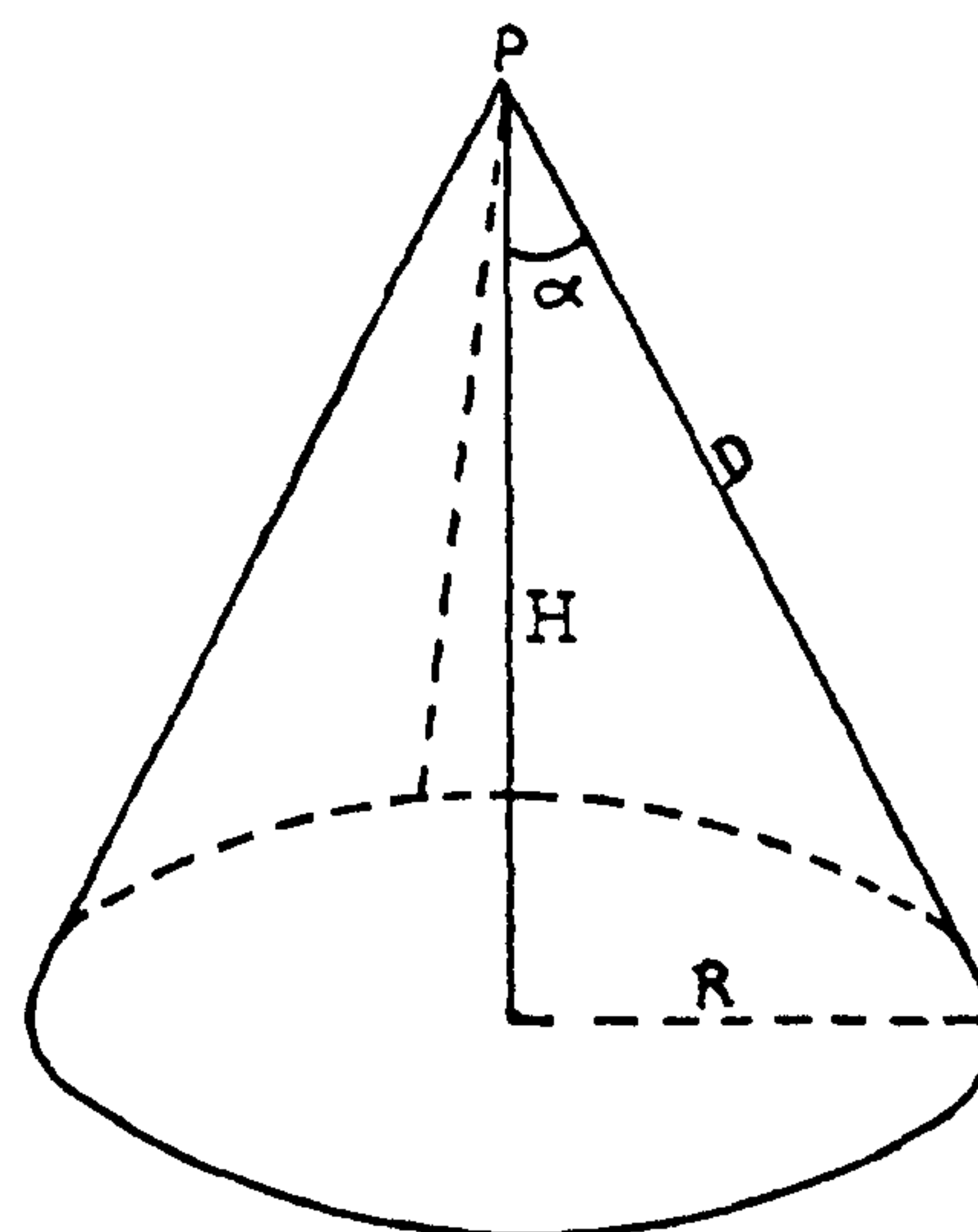
B

THE FORMATION OF A DART

FIG. 21



A



B

THE PRINCIPLE OF ACHIEVING A THREE-DIMENSIONAL SHAPE
BY THE INSERTION OF A DART

FIG. 22

Fig. 22A shows a circle A with centre point P, radius D and angle of dart ϵ being the angle needed to convert the two-dimensional circle into a three-dimensional cone. Let R be the radius of this cone, 2α be the apex angle of this cone and let α be half of the apex angle. (See Fig.22B).

The circumference C of that cone (excluding ϵ) is given by the formula:

$$C = (2\pi - \epsilon) \times D \quad (6.3.1)$$

and the radius R of the cone by the formula:

$$R = \left(\frac{2\pi - \epsilon}{2\pi} \right) \times D \quad (6.3.2)$$

It may equally be noticed that the height of the cone H is given by either of the following two formulae:

$$H = \sqrt{D^2 - R^2} \quad (6.3.3)$$

$$H = \cos \alpha \times D \quad (6.3.4)$$

Hence, from equations (6.3.2), (6.3.3) and (6.3.4)

$$\cos \alpha \times D = \sqrt{D^2 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2 \times D^2} \quad (6.3.5)$$

Hence,

$$\cos^2 \alpha \times D^2 = D^2 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2 \times D^2 \quad (6.3.6)$$

and

$$\cos^2 \alpha \times D^2 = D^2 \left(1 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2 \right)$$

Hence,

$$\cos^2 \alpha = 1 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2 \quad (6.3.7)$$

from which

$$\cos \alpha = \sqrt{1 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2} \quad (6.3.8)$$

Thus, formula (6.3.8) provides the relationship between the angle of dart ϵ on the shaped pattern and the half apex angle α of the circular cone. Furthermore, it may also be seen that if a relationship is required between height H and generator D and the half apex angle α of the cone, the following formula is available:

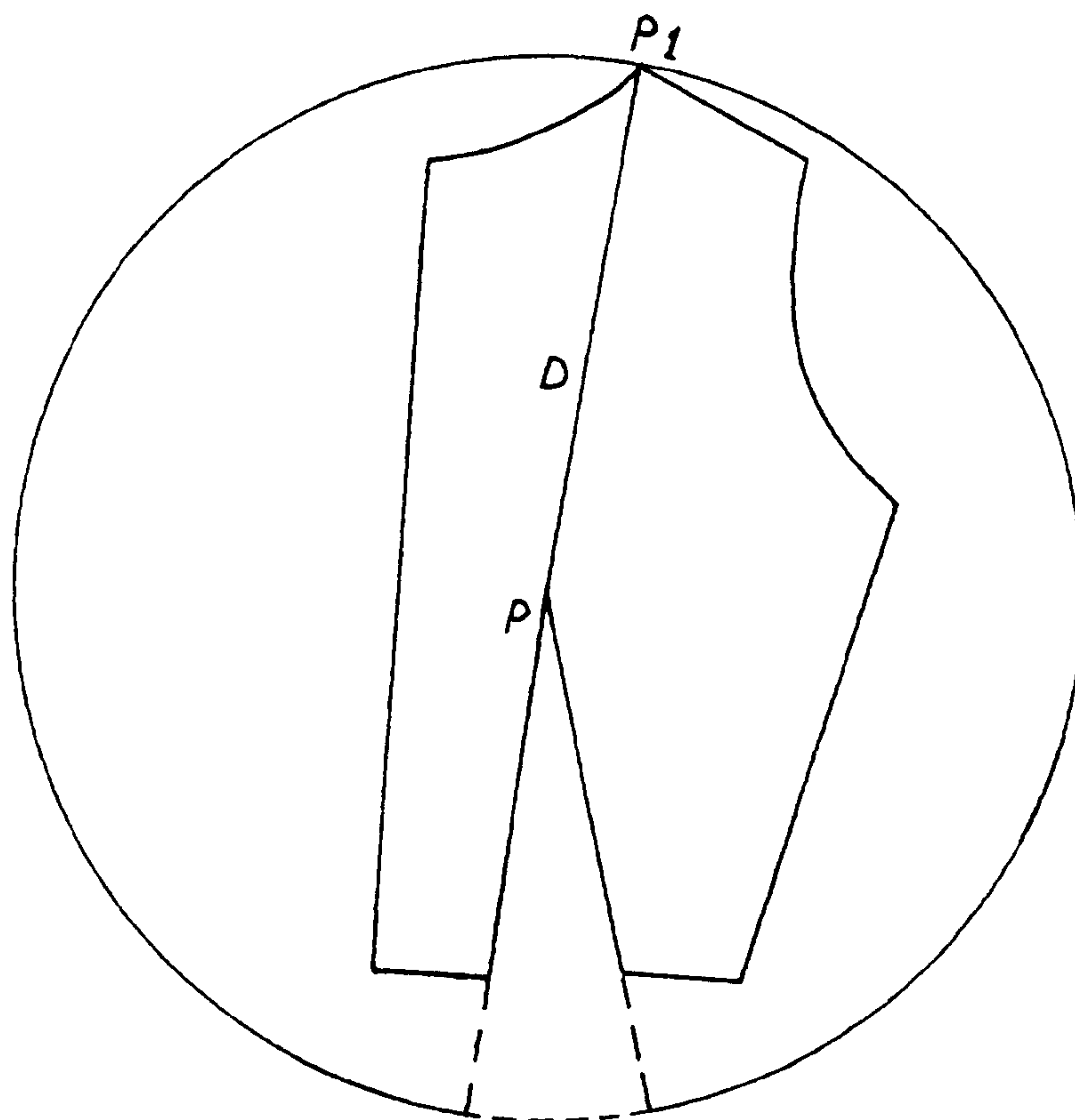
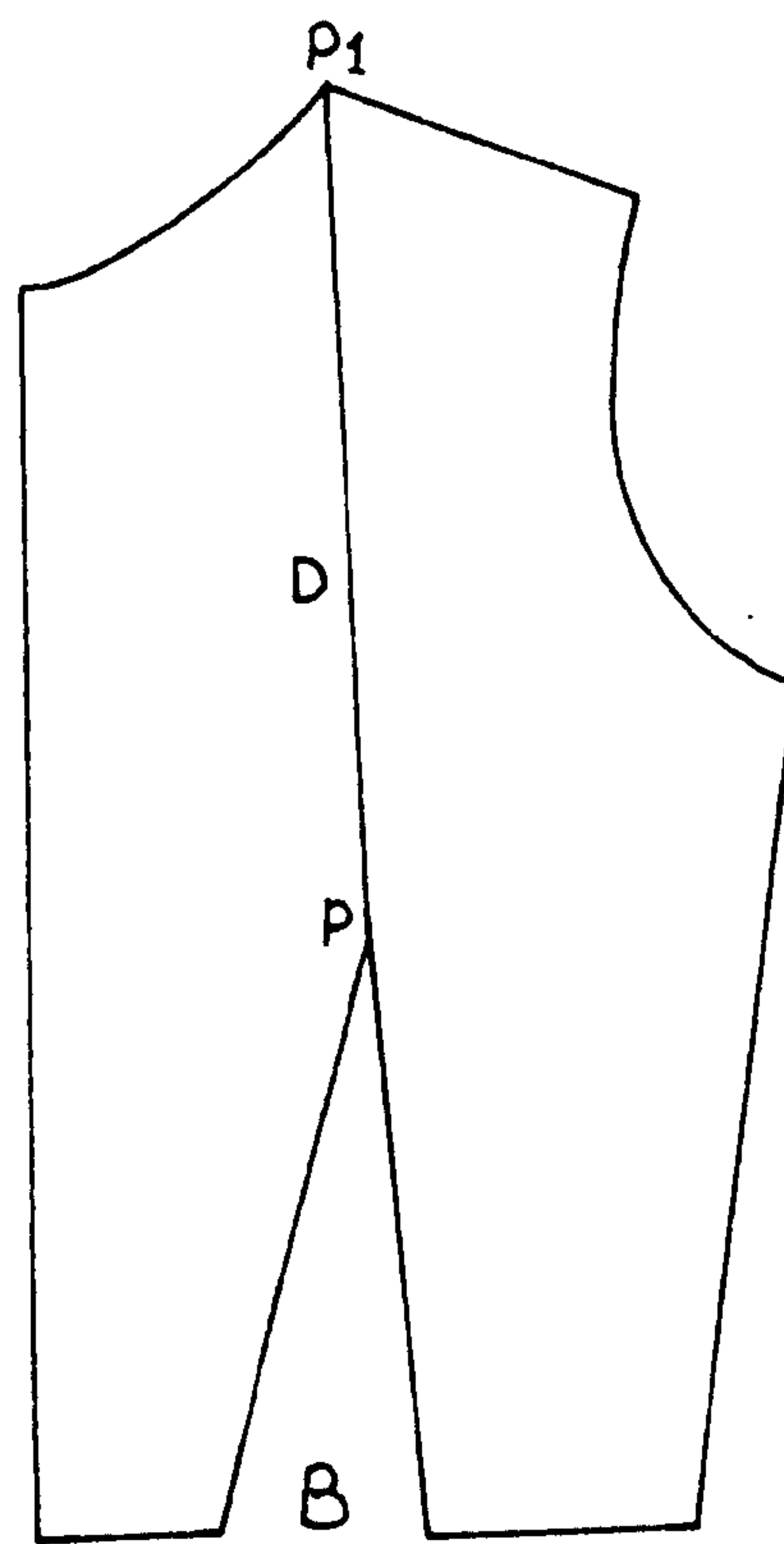
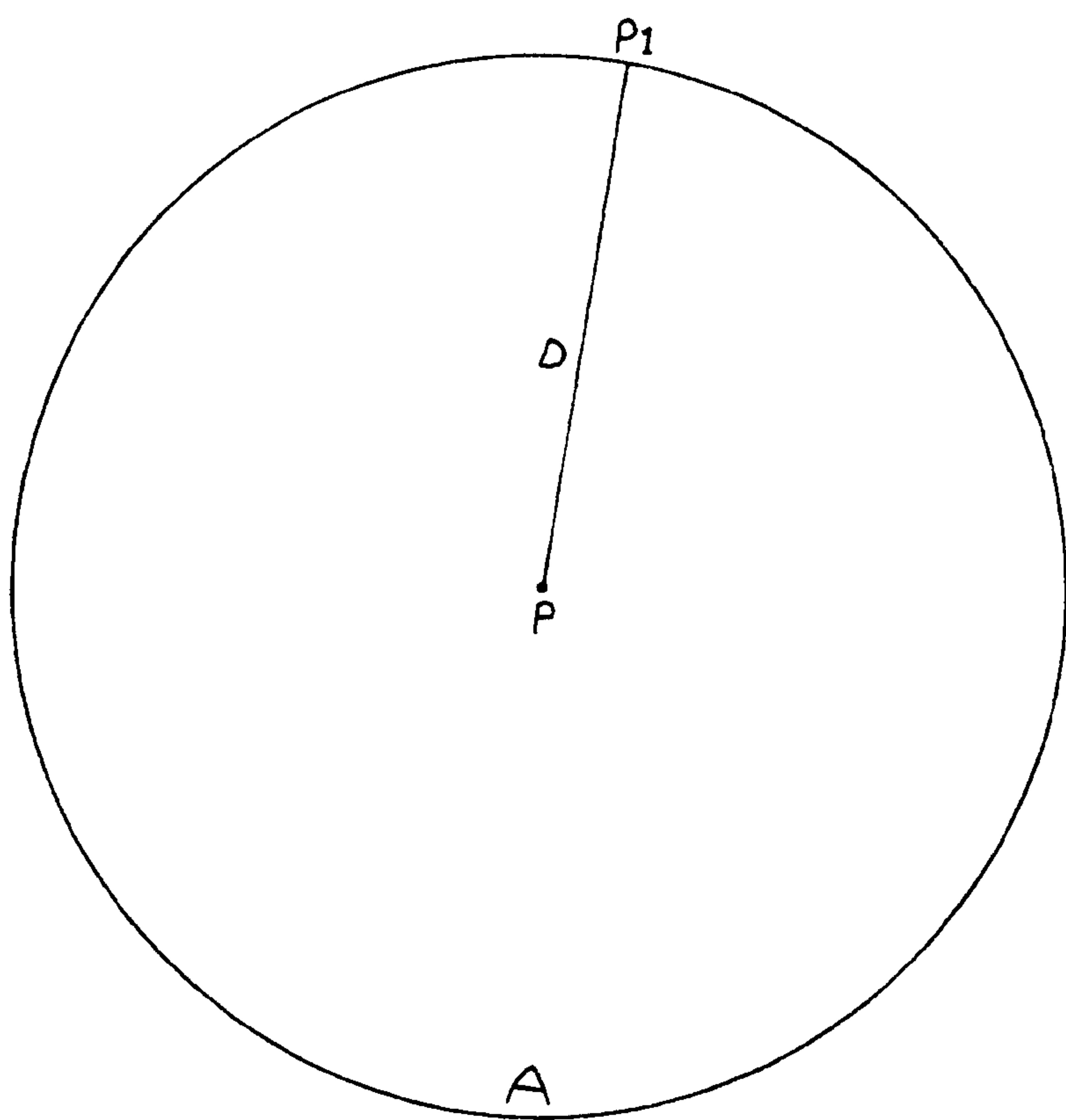
$$\frac{H}{D} = \sqrt{1 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2} \quad (6.3.9)$$

Upon analysing the relationship provided by (6.3.8), it is obvious that half apex angle α and angle of dart ϵ are related to each other without being dependent on any other cone features such as generator, height etc., and if a flat surface is to be converted into a cone, a knowledge of the required apex angle of the cone may be used to calculate the accurate angle of dart ϵ needed to be inserted into the flat surface.

In common practice, when garments are made to fit the human body, the body is divided into two sections, front and back, which are again divided into two vertical sections resulting in half-front and half-back panels. Individual patterns are thus made for each of these panels.

When considering the upper part of the body, examination of the two bodice panels reveals, (particularly in the case of the female body) that each of the panels may be looked upon as individual sections of the body which may be effectively represented by separate cones. It will be realised that the cones will not be right circular ones, nor will the outer shell of the cone, when fitting the body, be always straight-edged.

This fact is best illustrated by Fig. 23, where circle A and panel pattern B are superimposed. It will be appreciated that only one point on the outer line (P₁) shares both circle and pattern and thus, pattern B is only part of a circular cone and therefore could not be regarded as a right circular one. Furthermore, curvature of the pattern shell will be required to fit the body perfectly but this will be achieved by the flexibility of the cloth from which the garment is made. Thus, a pattern constructed to fit the body shape may be regarded as a cone and if its shell has the correct altitude and apex angle to give a perfect fit to the body, the flexible characteristics of the cloth will allow for any curvature of the body.



THE RELATIONSHIP BETWEEN CONE AND BODY PANEL

FIG. 23

The argument overleaf suggests that the techniques of obtaining three-dimensional garments of satisfactory fit from flat fabric requires only the accurate establishment of the cone apex angle and altitude of each of the panels.

In practice however, the measurement of these parameters is virtually impossible to obtain to an acceptable tolerance and no apparatus is available which could conveniently be modified to measure these parameters.

With this concept in mind, the need therefore was to develop an alternative method of assessment of body shape which could be practically measured and would lead to an accurate description of the required pattern shapes to fit the body.

This method is described in the following chapter.

CHAPTER SEVEN

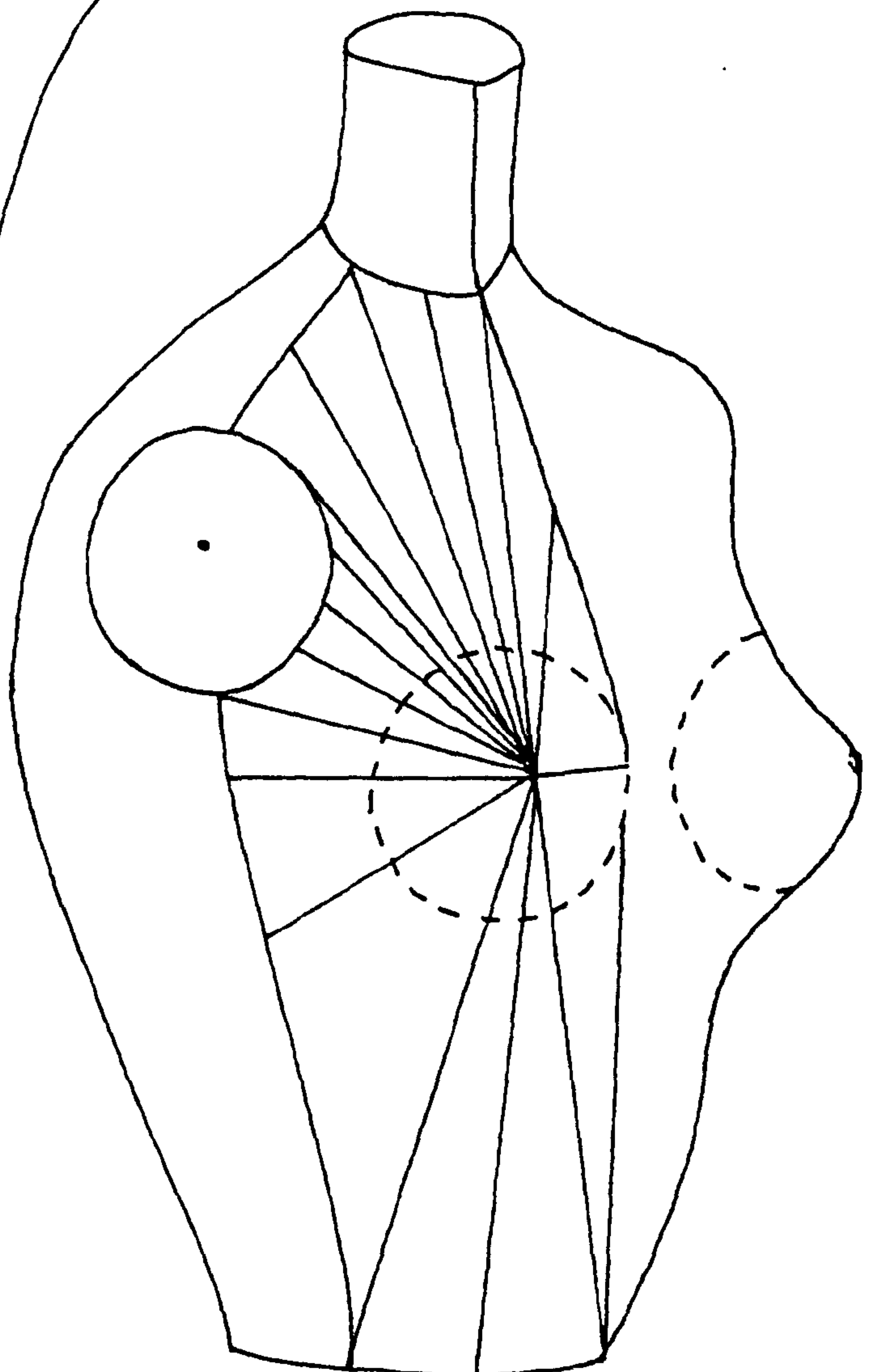
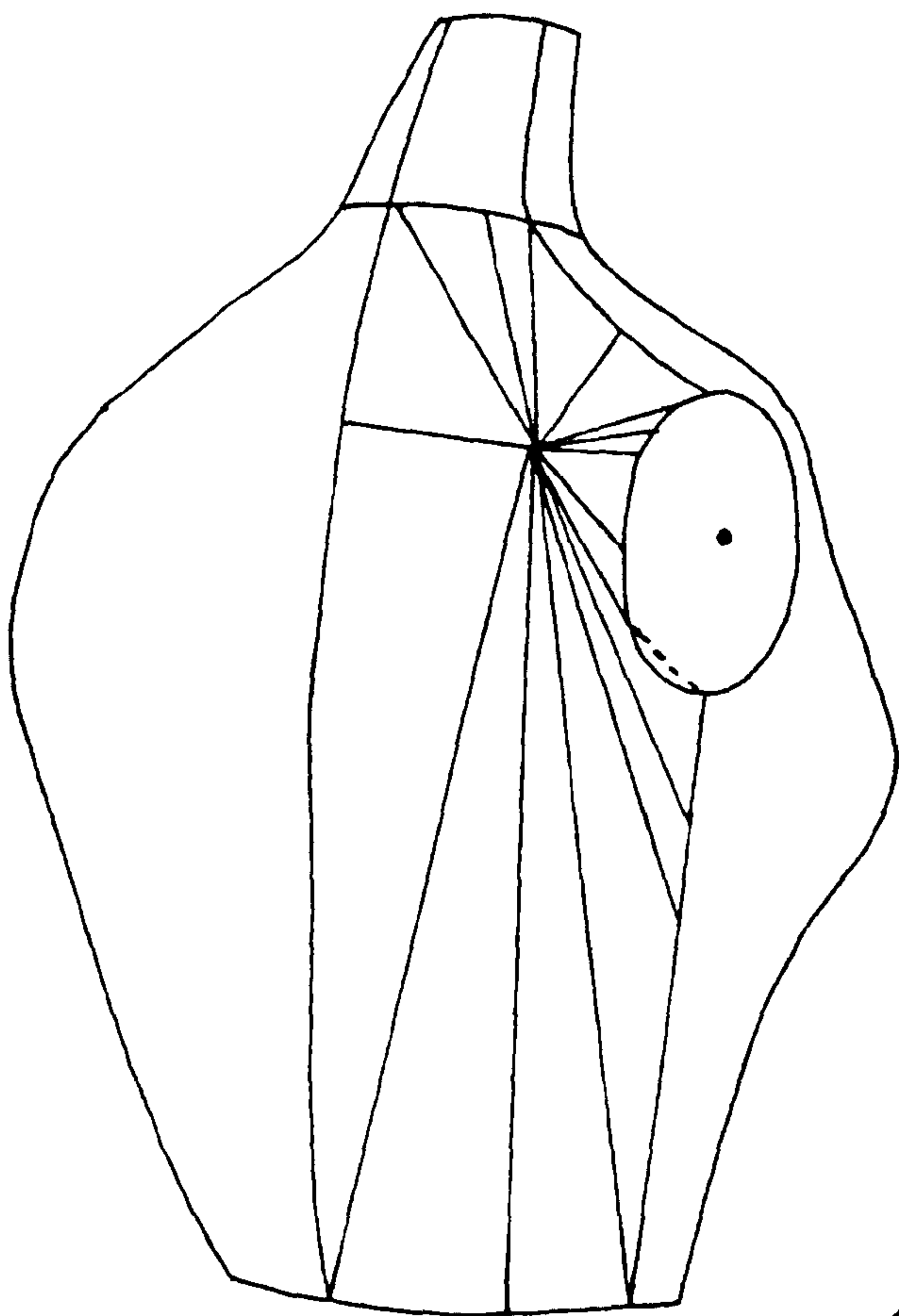
APPLICATION OF THE CONE PRINCIPLE TO A PRACTICAL METHOD FOR
OBTAINING THE THREE-DIMENSIONAL SHAPE OF THE HUMAN BODY

As described in chapter six, if the three-dimensional configurations of the human body are considered as a number of conical shapes, in order to obtain a garment of accurate fit by the insertion of darts, the sole requirements is to know the required apex angle of each individual conical section. If this is achieved, the flexibility of the fabric will be used to cause the surface of the conical sections to be curved rather than straight sided and for this purpose alone (i.e. the flexible and elastic features of the fabric will not be used in the plane of the fabric to get an adequate fit).

The practical problem is however, that the apex angle of each of the conical sections is not only not known, but also would be extremely difficult to measure. Hence, for practical body measurements some alternative method of measurement has to be considered.

After various considerations it was eventually realised that an alternative and more practical way of establishing the three-dimensional configuration of the body would be the division of each conical section of the body into small annular triangular sections. (See Fig. 24 where the shape of the body has been divided into a number of triangular sections).

As may be seen from this figure, the distances of each leg of each triangular section may be calculated by the formula overleaf.



DIVISION OF THE BODY INTO TRIANGULAR SECTIONS

FIG. 24

$$D = \sqrt{(X_n - X_{n+1})^2 + (Y_n - Y_{n+1})^2 + (Z_n - Z_{n+1})^2} \quad (7.1)$$

where,

D = distance between the points in a three-dimensional environment. Let the points be n and n + 1.

X_n = co-ordinate of X dimension of point n

X_{n+1} = co-ordinate of X dimension of point n + 1

Y_n = co-ordinate of Y dimension of point n

Y_{n+1} = co-ordinate of Y dimension of point n + 1

Z_n = co-ordinate of Z dimension of point n

Z_{n+1} = co-ordinate of Z dimension of point n + 1

From this information, using the 'law of cosines' formula, the angle that each of these triangular sections make at the apex point may be calculated as follows: (see Fig. 25).

$$\cos \gamma = \frac{a^2 + b^2 - c^2}{2ab} \quad (7.2)$$

where,

a = distance between C and B

b = distance between C and A

c = distance between A and B

ϕ = angle at point A

β = angle at point B

γ = angle at point C (apex angle)

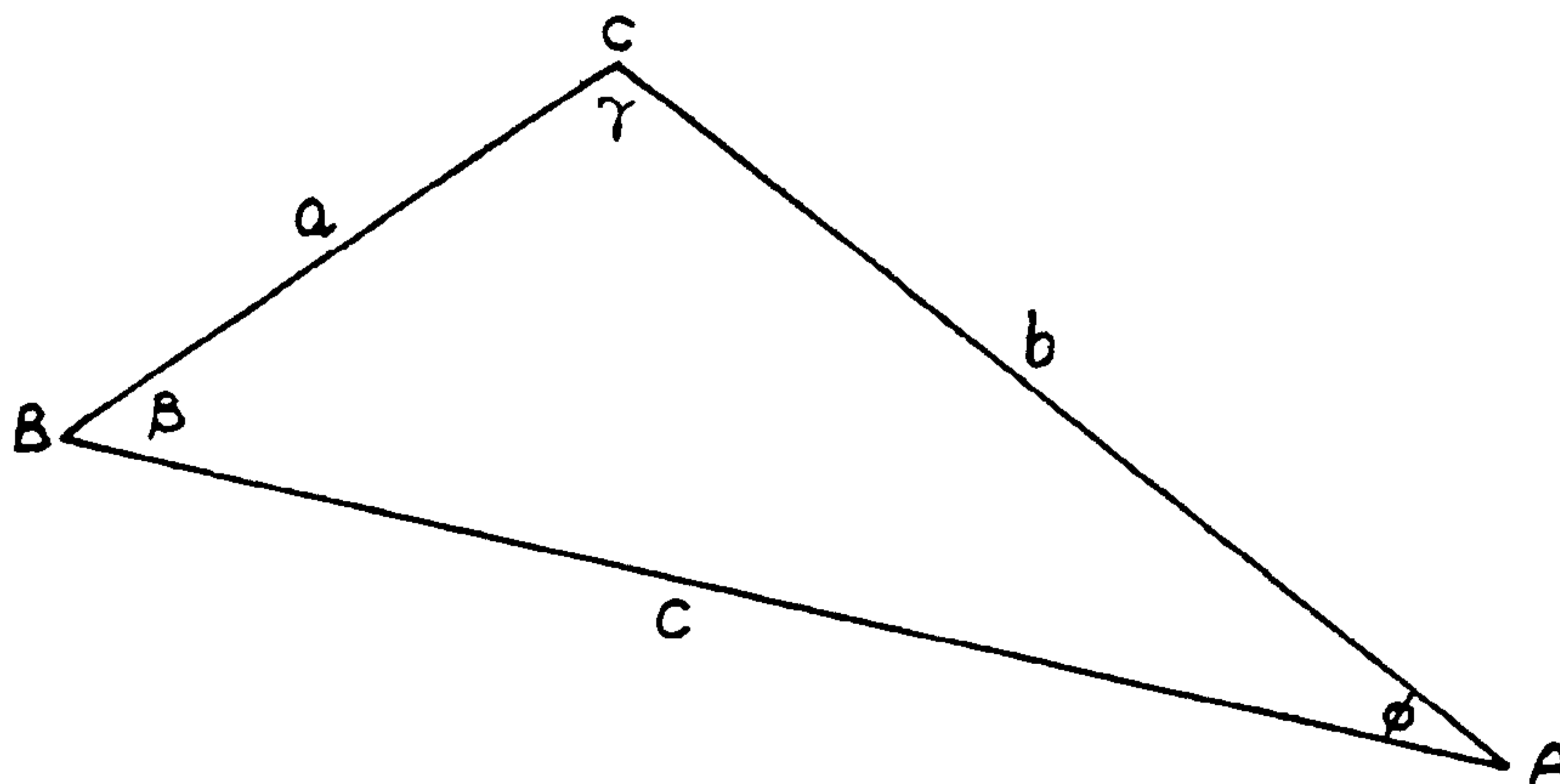


FIG. 25

The summation of all of these triangular sections will give the outline of the pattern shape and the sum of all the angles will give the angle of the fabric required at the apex point; the angle of the section which will be required to form the dart (ϵ) will be given by the following formula:

$$\epsilon = 2\pi - \sum_{i=1}^n \gamma(i) \quad (7.3)$$

where,

ϵ = the angle of dart

2π = the sum total of the angles radiating around the centre point of a flat surface

$\sum_{i=1}^n \gamma(i)$ = the sum total of the angles pivoting around the apex point of a three-dimensional conical shape

n = number of angles

This angle of dart will then, of course, be related to the apex angle of the conical shape as given by the formula (6.3.8).

This method suggests therefore, that the production of a pattern of acceptable fit can be achieved for each conical section of the body by measurements of the three-dimensional co-ordinates of the crucial shaping points on the body alone.

As an example to prove the accuracy of this method a cone, on which a number of points were selected on its surface (see Fig. 26) was measured in three-dimensions.

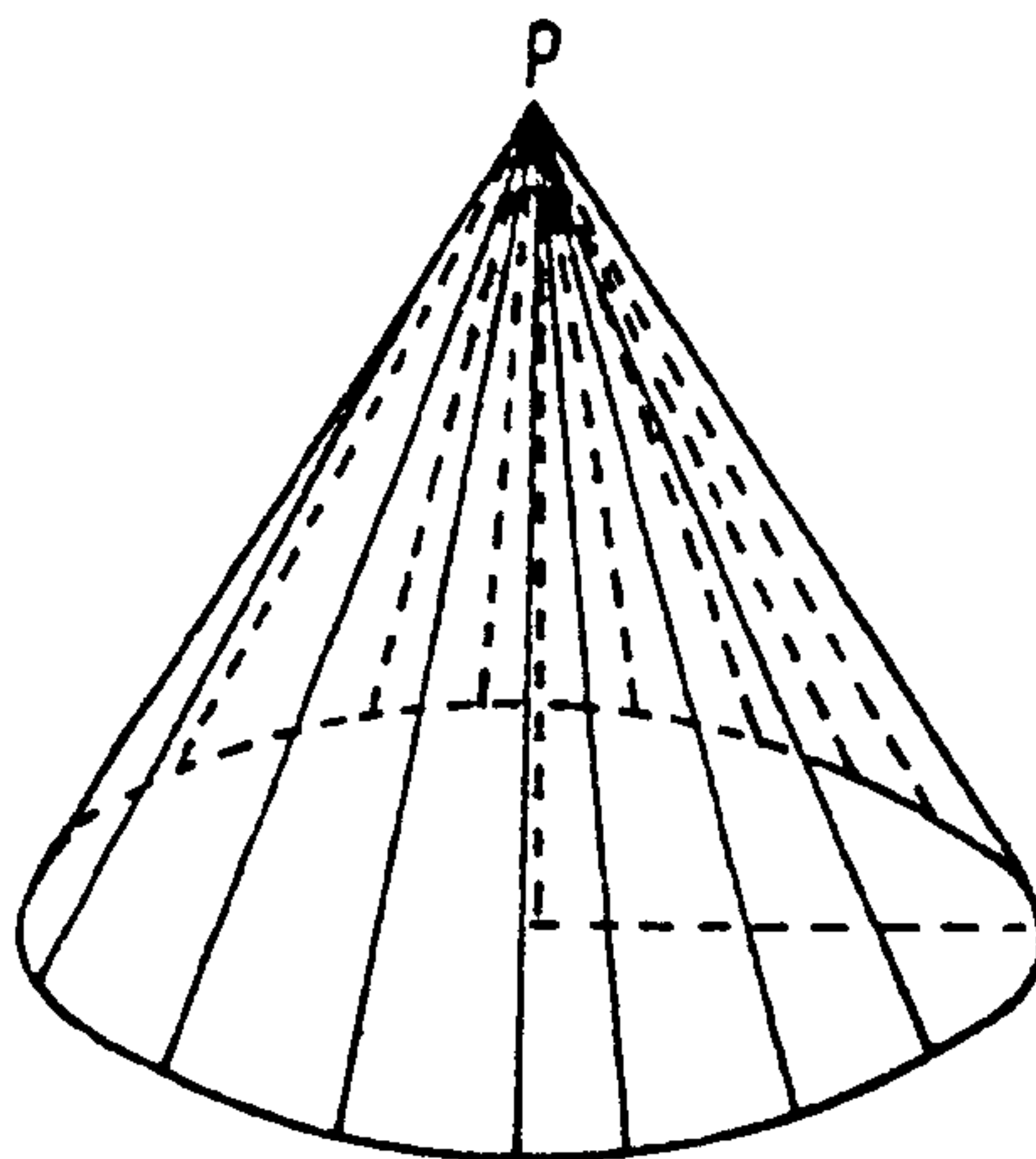
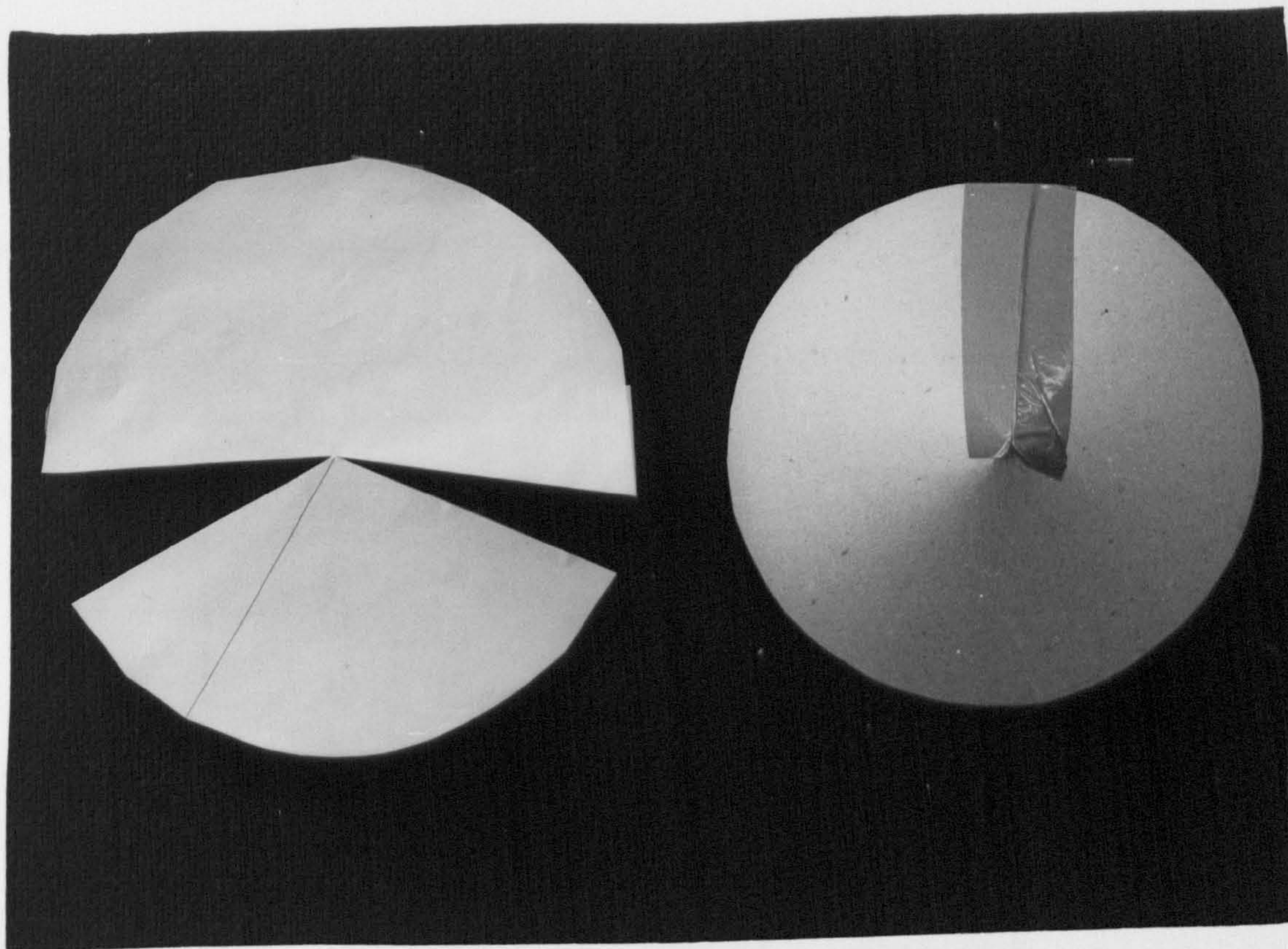


FIG. 26

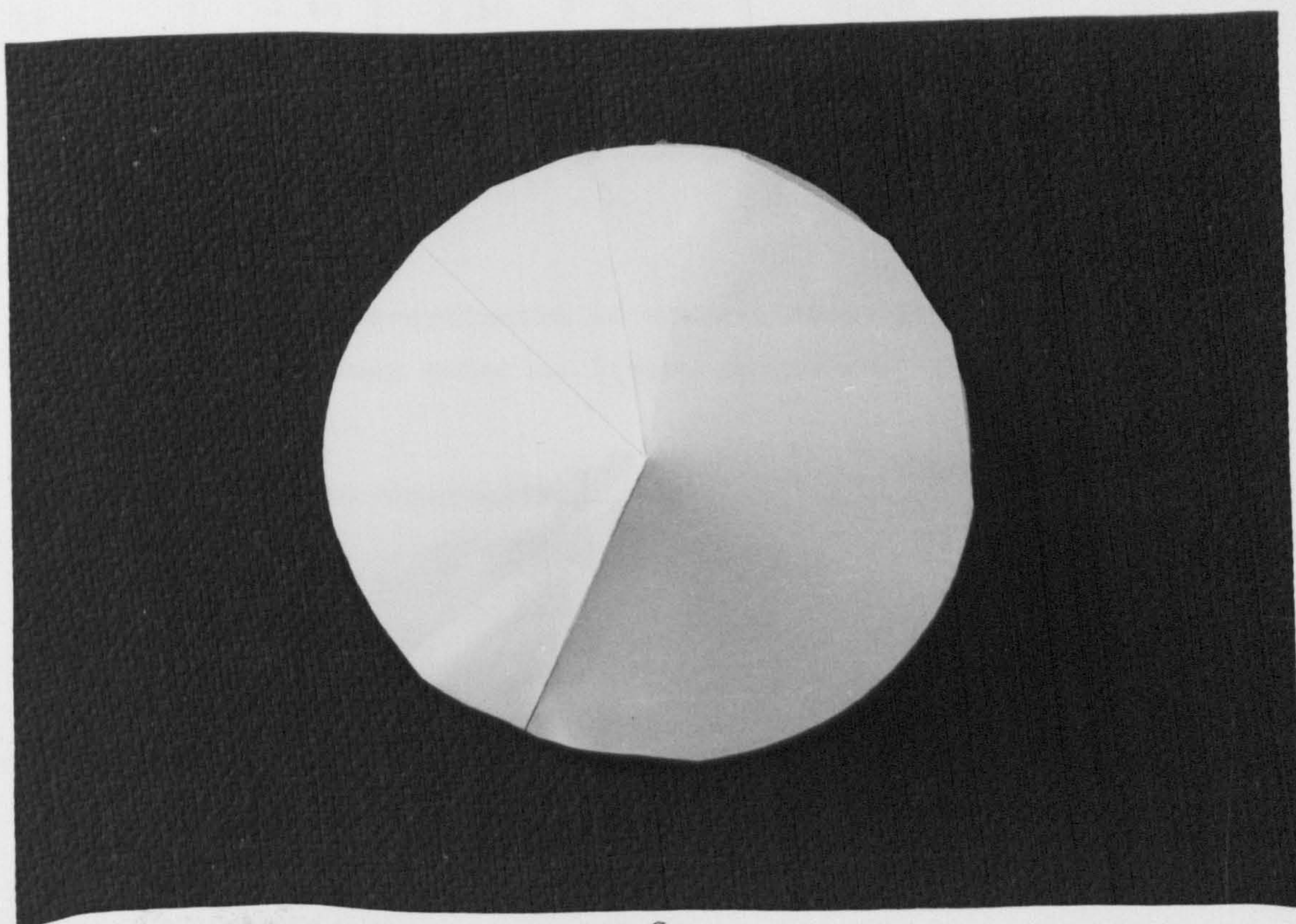
From this information, the distances between the apex point and the crucial shaping points (see Table 2), the distances between the crucial shaping points and the angles that each of the triangular section illustrated in Fig. 26 makes at the apex point and the angle of dart needed to insert into a pattern to fit the cone perfectly (see Table 3), were calculated. Based on this information, a pattern was drafted. When put on the cone, as may be seen in Fig.27c it was found to fit smoothly and accurately.

As may be observed from the argument presented so far, the establishment of the angle of dart (ϵ) will provide the apex angle (α) of the cone and the altitude of the cone may be determined from the apex angle and the length of its generator. This can be achieved by inserting the angle of dart (ϵ) into formula 6.3.8 and the resultant apex angle (α), together with the cone generator (D), into formula 6.3.9 .



A

B



C

FIG. 27

Thus, the principle of obtaining an accurate description of the cone shape by measuring the three dimensional co-ordinates of the crucial shaping points is established.

Point No.	Co-ordinate			Distance
	X	Y	Z	
1	9.30	9.50	5.00	-
2	18.50	9.50	0.00	10.47
3	18.10	12.00	0.00	10.43
4	16.70	15.00	0.00	10.49
5	9.30	18.70	0.00	10.47
6	6.00	18.10	0.00	10.48
7	1.90	15.00	0.00	10.48
8	0.50	12.20	0.00	10.48
9	0.10	9.50	0.00	10.47
10	0.50	6.80	0.00	10.48
11	1.90	4.00	0.00	10.49
12	6.00	0.90	0.00	10.48
13	9.30	0.30	0.00	10.47
14	14.60	2.00	0.00	10.46
15	16.70	4.00	0.00	10.49
16	18.20	7.00	0.00	10.51

TABLE 2

Three-dimensional co-ordinates of crucial shaping points and distances between point no.1(apex point) and crucial shaping points.

Distances and co-ordinates in cm.

Point No.	Distance	Angle
2 - 3	2.53	0.24
3 - 4	3.31	0.32
4 - 5	8.27	0.81
5 - 6	3.35	0.32
6 - 7	5.14	0.50
7 - 8	3.13	0.30
8 - 9	2.73	0.26
9 - 10	2.73	0.26
10 - 11	8.07	0.30
11 - 12	5.14	0.50
12 - 13	3.35	0.32
13 - 14	5.56	0.54
14 - 15	2.90	0.28
15 - 16	3.35	0.32
16 - 2	2.52	0.24
Angle of dart (ϵ)		0.77

TABLE 3

Distances and angles between crucial shaping points
and angle of dart.

Distances in cm.

Angles in radians.

7.2 APPLICATION OF CONE PRINCIPLE TO OBTAIN AN ACCURATE DESCRIPTION OF BODY SHAPE

When an attempt is made to apply the method described in the previous section to the human figure, a substantial assumption is made. It assumes that for each of the triangular sections considered, the bending of the fabric out of the surface of the conical shape, is not of crucial importance. For this to be so, the sections considered have to be sufficiently small to make the effect of this assumption a small one. However, the smaller the sections the greater the number of body co-ordinates that would be required, which would cause practical problems for body measurement in an acceptable period of time.

Consideration of this problem led to realisation that for many parts of the body the bending of the fabric out of the cone plane was small and therefore could be ignored and only in certain areas was the effect large enough to affect the results.

7.2.1 Problems associated with implementing the cone principle to obtain an accurate description of body shape

It will be evident that formula (7.1) will give the distances between any two points on the body measured along a straight line. However, on some parts of the body the actual shape between these two points will be curved so that the distance between these points will, in this case, be longer than that calculated.

Thus, in these parts of the body, the length of the sections of the pattern calculated from this formula will be less than that required to obtain a garment of satisfactory fit; therefore, to obtain pattern pieces of the correct dimensions to fit the body, some allowances will

be required for the curvature of the body. It will also be recognised, that the curved shaped lines on different areas on the body may be either concave or convex and whereas the curves are for the most part convex on the back panel, they are concave on the front panel.

(See Fig. 28).

Further consideration of this problem revealed, that when a pattern is constructed for clothing purposes, a different application is required for the two different types of curved lines. Viz. when a concave shape is to be applied to the flat pattern, the straight distance between the two points is the required length of the pattern pieces needed to achieve a garment of satisfactory fit whereas, when a convex shape is applied, the straight length will in general not be sufficient to fit the curve of that part of the body; the actual curved length of the body in that area will therefore be the appropriate length.

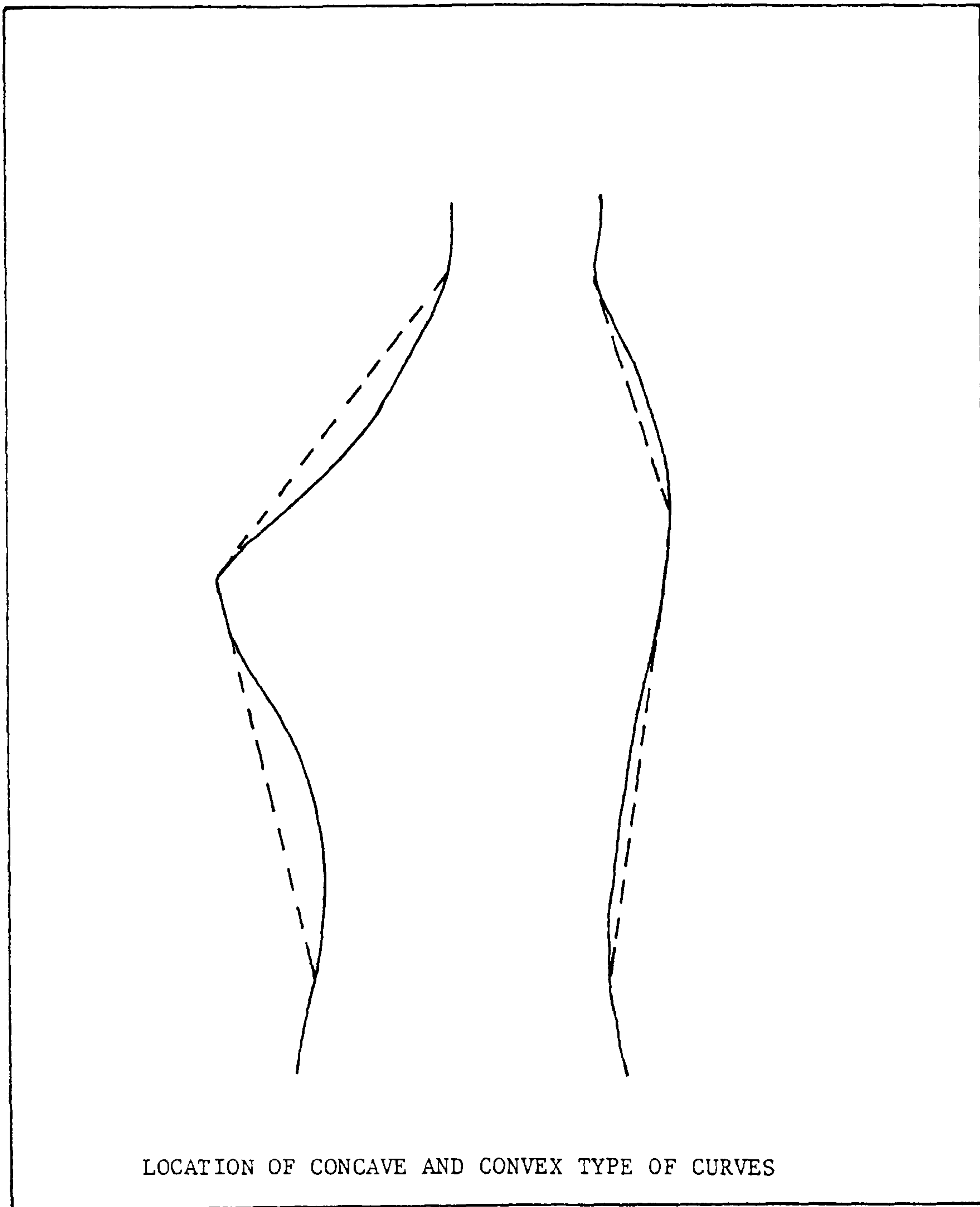


FIG. 28

7.3 METHOD FOR OBTAINING THE EXACT LENGTH OF CURVED SHAPED LINES

7.3.1 General Comment

A number of alternative methods were considered to deal with this problem, the two methods described below were adjudged to be the most useful and practical ones.

7.3.2 The Scanning Method

This method suggests that by measuring the intermediate points between any two extreme points of a curved line, and by calculating the distances between all the points on that line, the length will be provided by the summation of all these distances. The accuracy of the length of the line will be related to the number of intermediate points measured so that for higher accuracy a larger number of measurements would be required, although this would cause problems in measuring these points in an acceptable period of time. However, it is possible with todays modern electronic devices to scan the body in this way with great speed and accuracy.

7.3.3 The Factor Method

The curvature of the body is such that for many areas of it, the straight line distance between the crucial shaping points is sufficiently accurate to represent that length without any allowance for the curvature. Only in a limited number of places was an allowance necessary for the curvature of that part of the body. The realisation of this point led to the following method for estimating and allowing for the body curvature.

The distance between two points on a curved shaped line may be calculated from the linear distance between these two points if an appropriate factor for that part of the body is known, this factor being the ratio

$$\frac{\text{curved length}}{\text{linear length}}$$

Thus, when the shape of the body between the points is relatively flat or concave in shape, the factor would be 1.0. The more convex the shape the greater would be the curvature factor. Such factors may be known by tailors; alternatively, they may be obtained by measurements on a range of people or from conventional workroom stands.

7.3.4 The Method used

In practice, in the case of the work described in this thesis, the factor method has been used and the appropriate factors are given in chapter 11.

CHAPTER EIGHT

THE REQUIREMENTS AND DESIGN OF A MEASURING FRAME TO MEASURE THREE-DIMENSIONAL BODY CO-ORDINATES

As already mentioned, the methods used traditionally in the clothing trade to determine the shape of a human body are far from accurate. Since it is clear that body shape is the most important aspect of good fit, a new approach to body shape determination is called for. However, the methods developed for measuring the body's three-dimensional shape for anthropometric studies, and which were described in chapter 3 cannot be adopted for clothing purposes since they are time consuming, require highly skilled labour and are primarily designed to measure body surface and not three-dimensional body shape.

This being the case, a new apparatus for measuring the body in three-dimensional form had to be developed and a new approach to converting that data into a flat pattern had to be established.

In attempting to design a measuring frame suitable for arriving at the accurate three-dimensional shape of the human body, a different approach to the assessment of body shape had to be established.

Although the methods developed and described by Neath, Hutchinson and J. Sangermano, have involved the use of new techniques and measuring frames which facilitated the process of measuring; in all cases the garment dimensions were assessed by the use of the tape measure, a method which has already been described as an unreliable and inaccurate one.

To improve on these methods therefore, an alternative apparatus or frame was required whose principle was not based on the use of the tape measure.

The new method which was developed based on the mathematical principle that every line is represented by an infinity of points. Since a body can be represented by circumferential and length lines, if all the points which constitute these lines are known, the shape of the body is accurately described by a knowledge of these points.

Mathematically, this concept is simplified, since if the lines are reduced to a series of straight lines, the only points required still to specify the total body shape, are the extreme points of each straight line section.

Since the body is of a three-dimensional form, these points need to be specified by the three-dimensional co-ordinates X, Y and Z, where

- (i) X is a measure of the horizontal displacement of the point in a width direction.
- (ii) Y is a measure of the vertical displacement of the point in a length direction.
- (iii) Z is a measure of the horizontal displacement of the point in a depth direction.

(See Fig. 29)

All of these dimensions will be required to be measured with reference to a fixed point which can be located either on the surface of the body or inside the body, or at a fixed place outside the body.

The chief requirements of the reference point is that it should be clearly defined, easy to measure and easily located.

The reference point chosen for the work described in this thesis was the hip level/spine level cross point, which can be defined as the most prominent point on the back hip area of the body. (See Fig. 30).

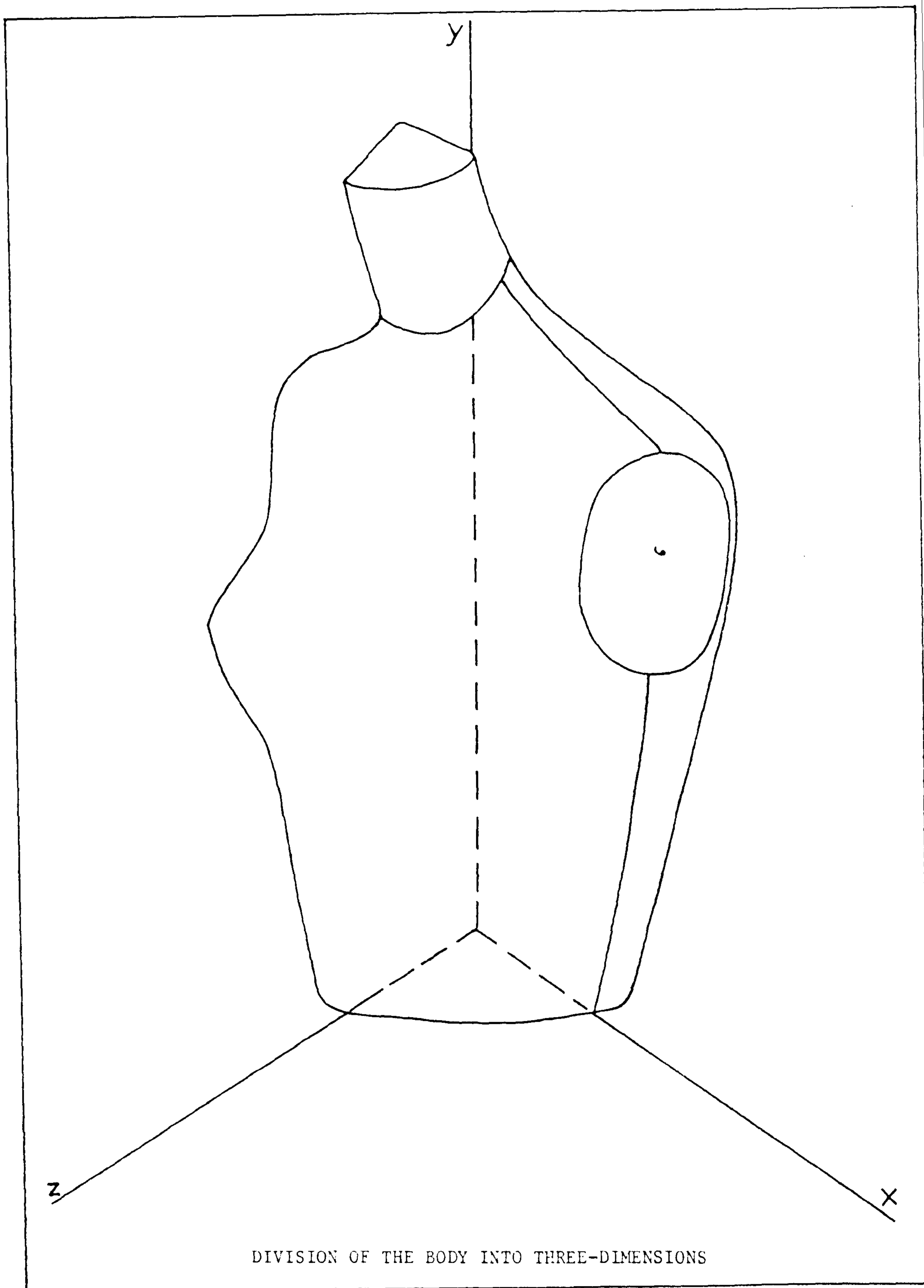
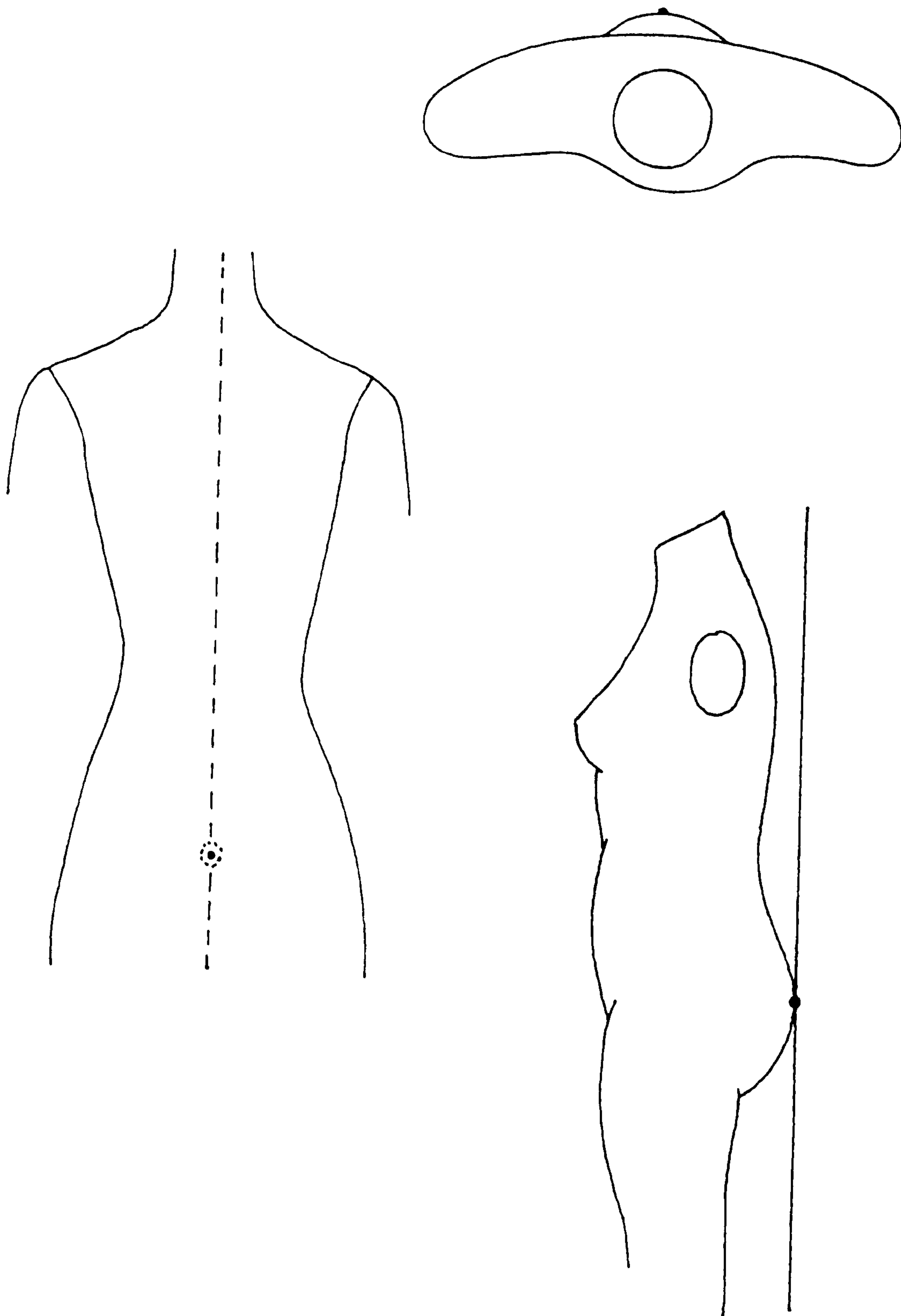


FIG. 29



LOCATION OF REFERENCE POINT

FIG. 30

The apparatus which eventually evolved to meet the requirements for assessing the body shape accurately was designed to meet the following criteria:

- (i) to enable the measurement of the human body to be reliable and accurate, without causing discomfort to the subject being measured;
- (ii) to enable a minimum of subject involvement;
- (iii) to be manually operated;
- (iv) to be easy to align and operate;
- (v) to enable it to be used in measuring workroom stands as well as the human body;
- (vi) to be portable;
- (vii) to be cheap to build and maintain.

A frame designed to meet the above requirements and to measure workroom stands is shown in Fig. 31, and consists of:

- (i) a base (A) which measures 50 x 50 cm;
- (ii) a vertical bar (B);
- (iii) a horizontal bar (C);
- (iv) a 'depth' slide bar (D);
- (v) a plumb line (E).

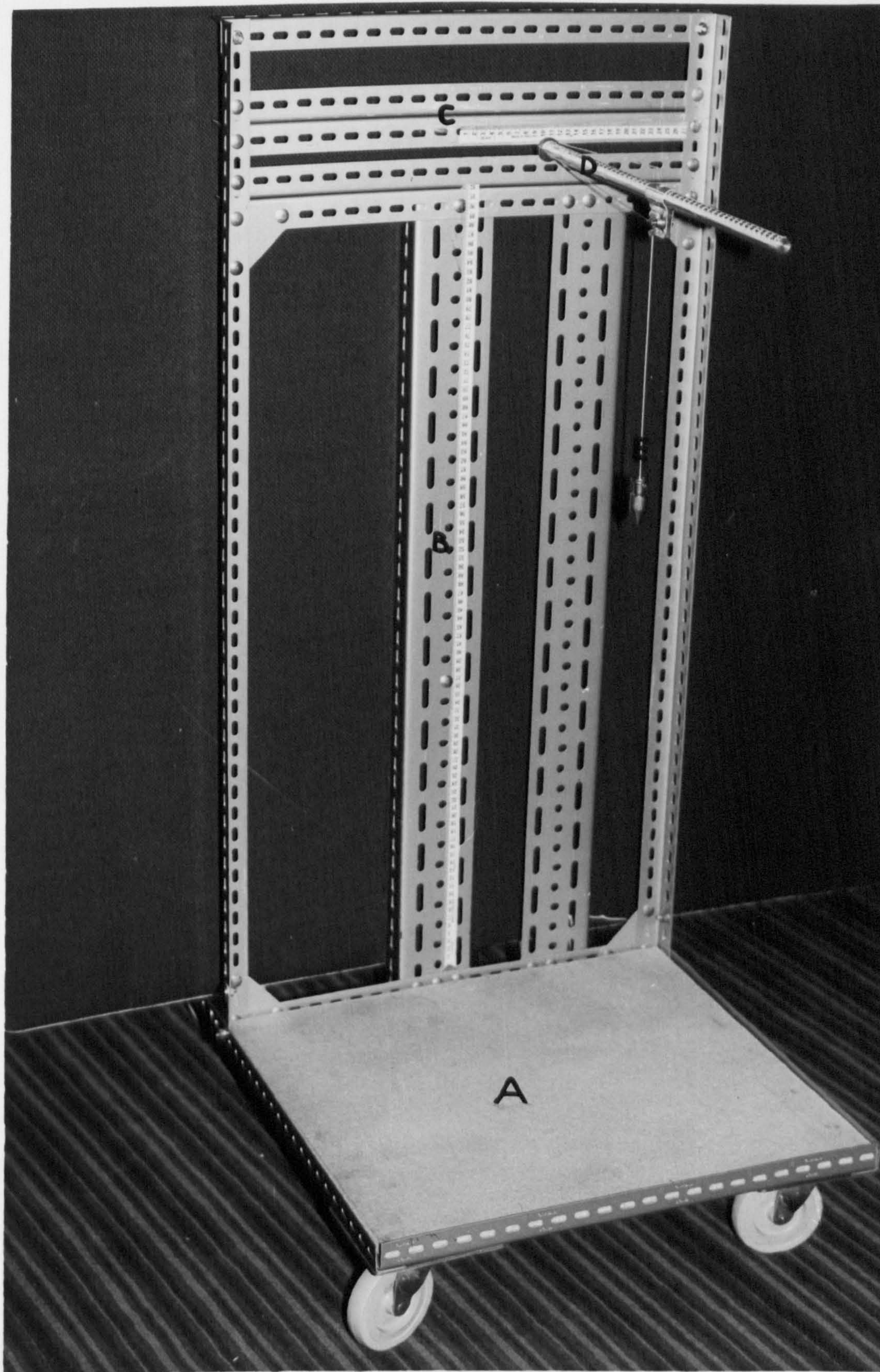


FIG. 31

(i) Base (A)

The base was designed in order to enable the human figure to stand in the correct position during the taking of the measurements. It was constructed of four metal L-shaped sections joined together to form a square measuring 50 x 50 cms. A 49 x 49 cm square of 16 mm plywood was placed on the metal frame base to form a platform for the subject to stand on. (See Fig. 31).

(ii) Vertical Bar (B)

The vertical bar was designed to provide the y dimension measurements. It was joined vertically to the base (A) and a measuring tape which was attached to it allowed the immediate reading of the vertical y co-ordinates (See Fig. 31).

(iii) Horizontal Bar (C)

The horizontal bar which was made from two metal L-shaped sections was designed to provide the x dimensional measurements. As may be seen from Fig. 32, the space between the two sections was designed to accommodate the z co-ordinate measuring bar (D). It was 50 cm long and supported by two uprights which were joined to the Base (A). The x dimension co-ordinate of each point was obtained by taking a reading from the tape measure which was attached to the Bar (C). (See Fig. 32).

(iv) 'Depth' Slide Bar (D)

The 'depth' slide bar was designed to provide the z dimension measurements and to allow the plumb line to slide to the exact position of the point being measured. As may be seen



FIG. 32

from Fig. 31, it is a tubular cross-section measuring 50 cm in length and fitted into the space provided between the two sections of the horizontal bar (C). A measuring tape was attached to it, allowing an immediate reading of the z co-ordinate. (See Fig. 33).

(v) The Plumb Line (E)

The plumb line (E) was joined onto the depth bar (D) by a metal sleeve (D_1) sliding on the depth bar (D). The plumb line was fixed to the sleeve and was in a position to be moved up and down according to the position of the point to be measured. (See Fig. 34).

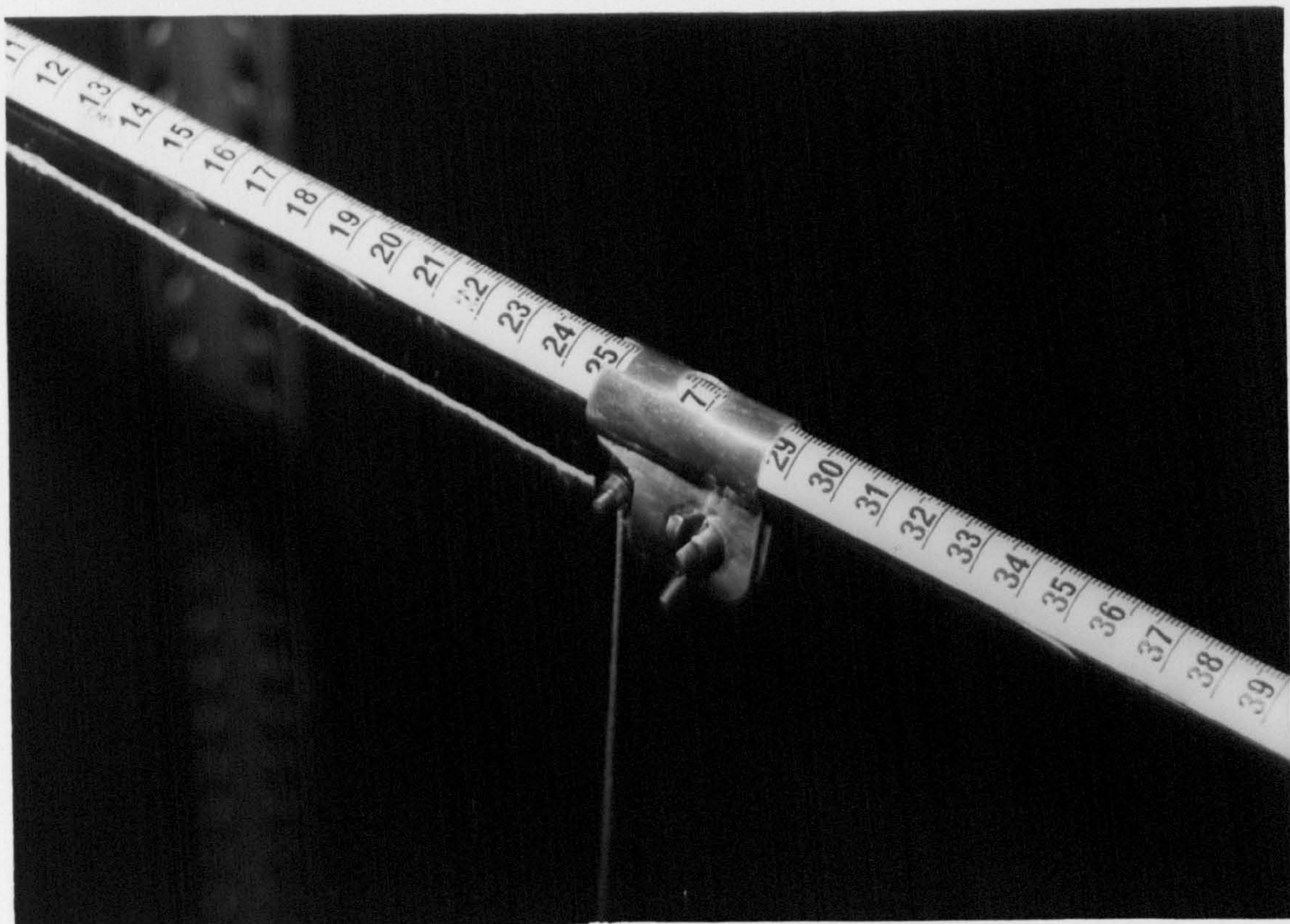


FIG. 33

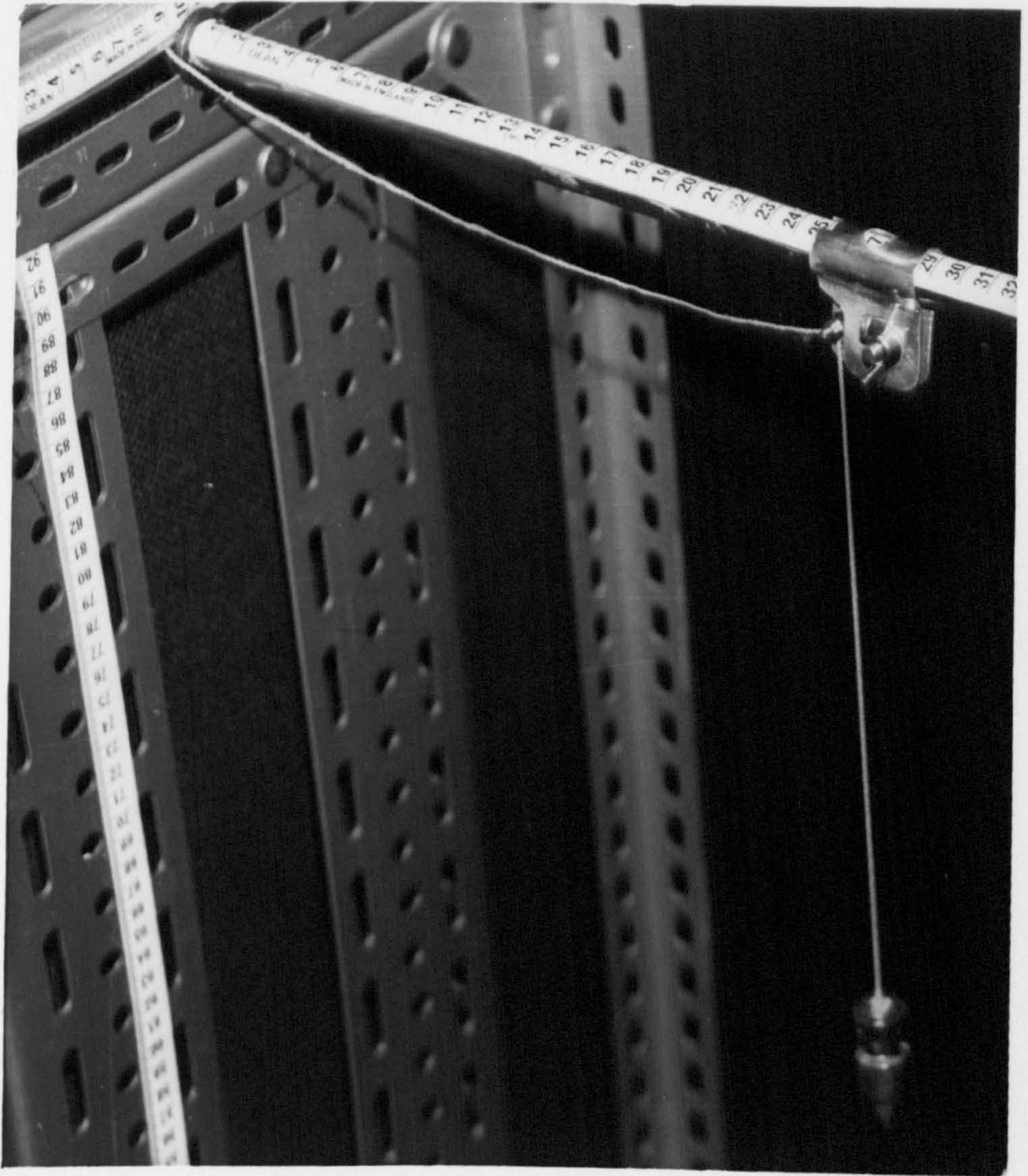


FIG. 34

8

CHAPTER NINE

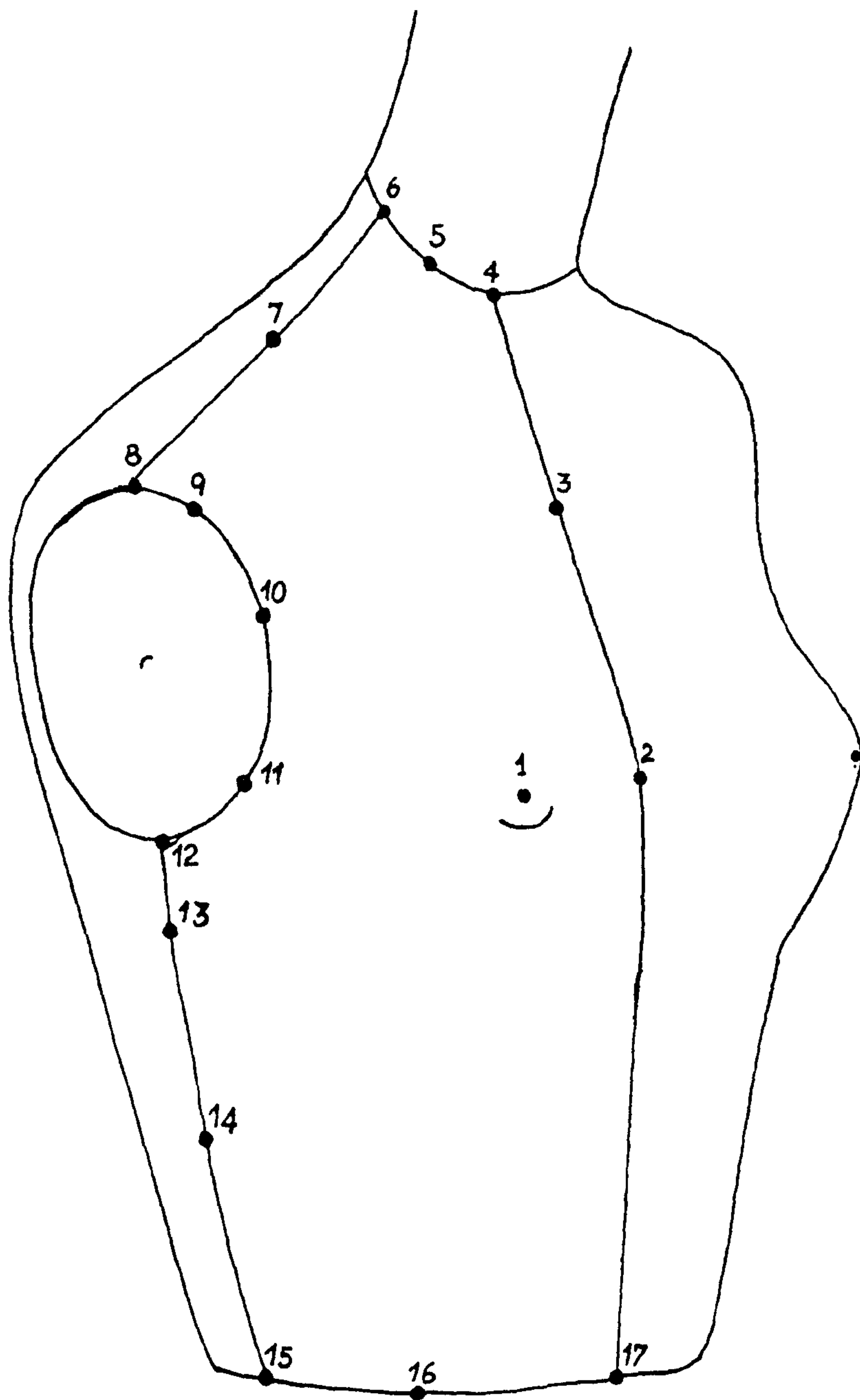
THE ASSESSMENT, LOCATION AND METHODS OF MEASURING THE
CRUCIAL SHAPING POINTS OF THE HUMAN FIGURE

If the shape of the body is to be represented by point co-ordinates rather than distances, for this representation to be an accurate one, the number of points selected have to be such that by joining these points together by lines of pre-determined curvature, the resultant outline is to all intents and purposes, identical with that of the body being represented.

For absolute representation, a very large number of points would be required, which would make the method immeasurable. In practice, it has been found that the number of points required to give a sufficiently accurate outline of the body are quite small.

For example, for the front bodice (see Fig.35), it will be seen that this part of the body can be accurately represented by the accurate positioning of 17 points, in that by drawing lines of curvature between these points, the outline is an accurate versimilitude of the original measured body.

These points are itemised overleaf. It will be noted that there is a concentration of points around the shoulder area. This is because it is at this part of the body that the greatest discontinuation in curvature occurs and also according to Hutchinson and others, this is critical for accurate fit.



LOCATION OF CRUCIAL SHAPING POINTS (FRONT PANEL)

FIG. 35

9.2 LOCATION OF CRUCIAL SHAPING POINTS

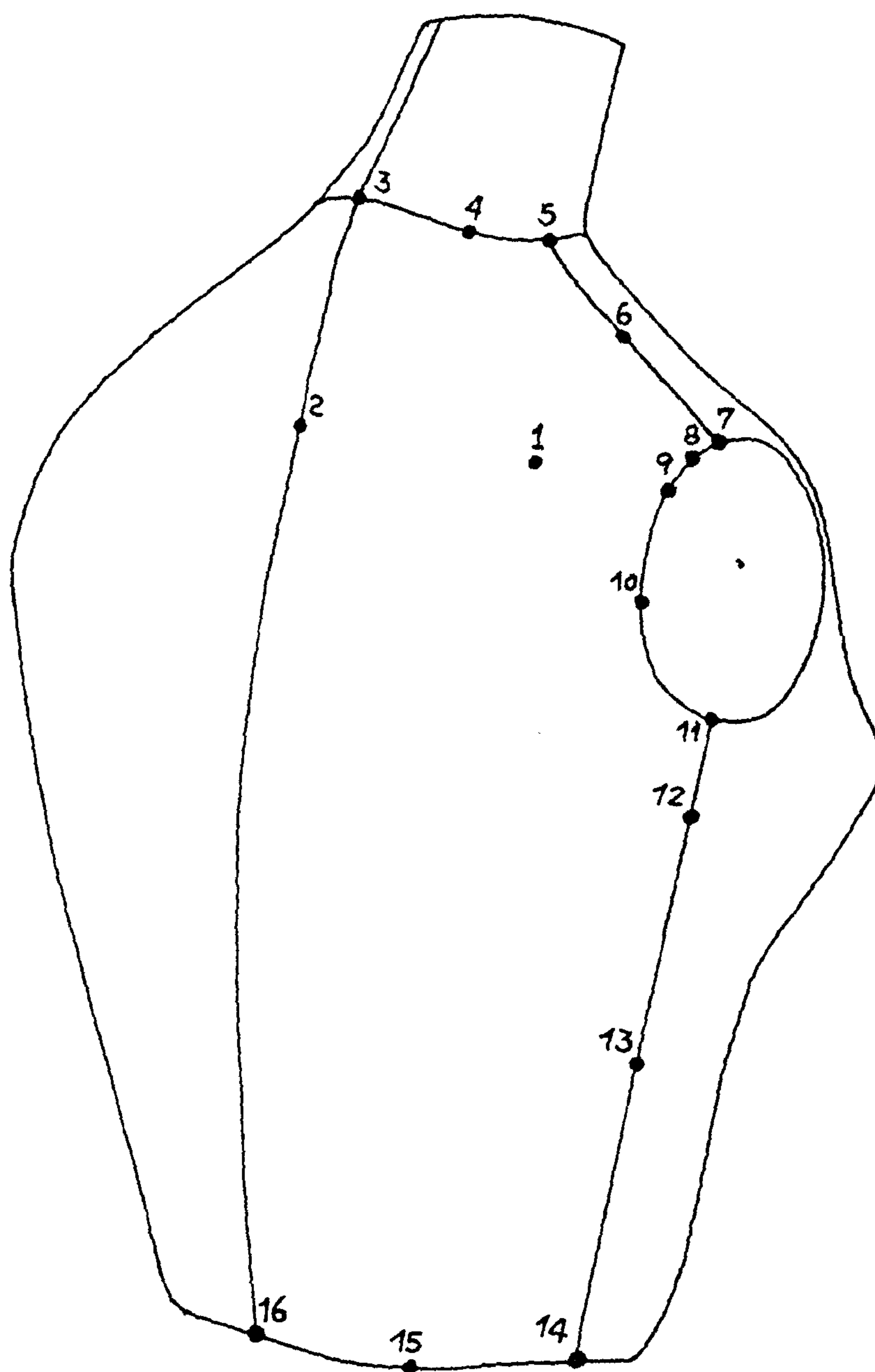
9.2.1 Front Panel (see Fig. 35)

1. Bust prominence point - the most prominent point of the bust.
2. Between bust prominence point - the point on the horizontal level half-way between one bust point and the other.
3. Mid-front point (optional) - at intersection point of mid-armhole half-way horizontal line, with centre front line.
4. Neck point - the lowest point in the front neck base.
5. Mid-neck point - half-way between point no.4 and no.6.
6. Shoulder/neck point - the highest point of the shoulder where it intersects the neck.
7. Mid-shoulder point - half-way between points no.6 and no.8.
8. End of shoulder point - end of shoulder bone.
9. Mid-upper armhole point - half-way between points no.8 and no.10.
10. Mid-armhole point - at intersection of across chest level with armhole line.
11. Mid-lower armhole point - half-way between points no.10 and no.12.
12. Under arm point - the lowest point in the armhole line.
13. Bust line point (optional) - bust line level on side seam.
14. Dart point on side seam (optional) - anywhere between points no.13 and no.15.
15. Waist side point - waistline level on side seam.
16. Mid-waist point - approx. half-way between points no.15 and no.17.
17. Centre waist point - at intersection of waistline level with mid-body vertical line.

9.2.2 Back Panel (see Fig. 36)

1. Shoulder blade - the most prominent point on the shoulder blade level.
2. Mid-back point - at intersection point of mid armhole horizontal line, with spine.

- | | | |
|-----|-----------------------------------|---|
| 3. | Cervical point | - the most prominent point of the seventh vertical vertebra, known in the clothing trade as nape of neck. |
| 4. | Mid-neck point | - half-way between point no. 3 and no.5. |
| 5. | Shoulder/Neck point | - the highest point of the shoulder where it intersects the neck. |
| 6. | Mid-shoulder point | - half-way between point no.5 and no.7. |
| 7. | End of shoulder point | - end of shoulder bone. |
| 8. | Mid-upper armhole | - half-way between point no.7 and no.9. |
| 9. | Mid-armhole point | - at intersection of across back line level with armhole line. |
| 10. | Mid-lower armhole point | - half-way between points no.9 and no.11. |
| 11. | Under arm point | - the lowest point in the armhole line. |
| 12. | Bust line point (optional) | - bust line level on sideseam. |
| 13. | Dart point on sideseam (optional) | - anywhere between point no.12 and no.14. |
| 14. | Waist side point | - waist line level of sideseam. |
| 15. | Mid-waist point | - approx. half-way between points no.14 and no.16. |
| 16. | Centre waist point | - at intersection of waist line and spine. |



LOCATION OF CRUCIAL SHAPING POINTS (BACK PANEL)

FIG. 36

9.3 MEASURING THE CO-ORDINATES USING THE NEWLY DESIGNED MEASURING FRAME

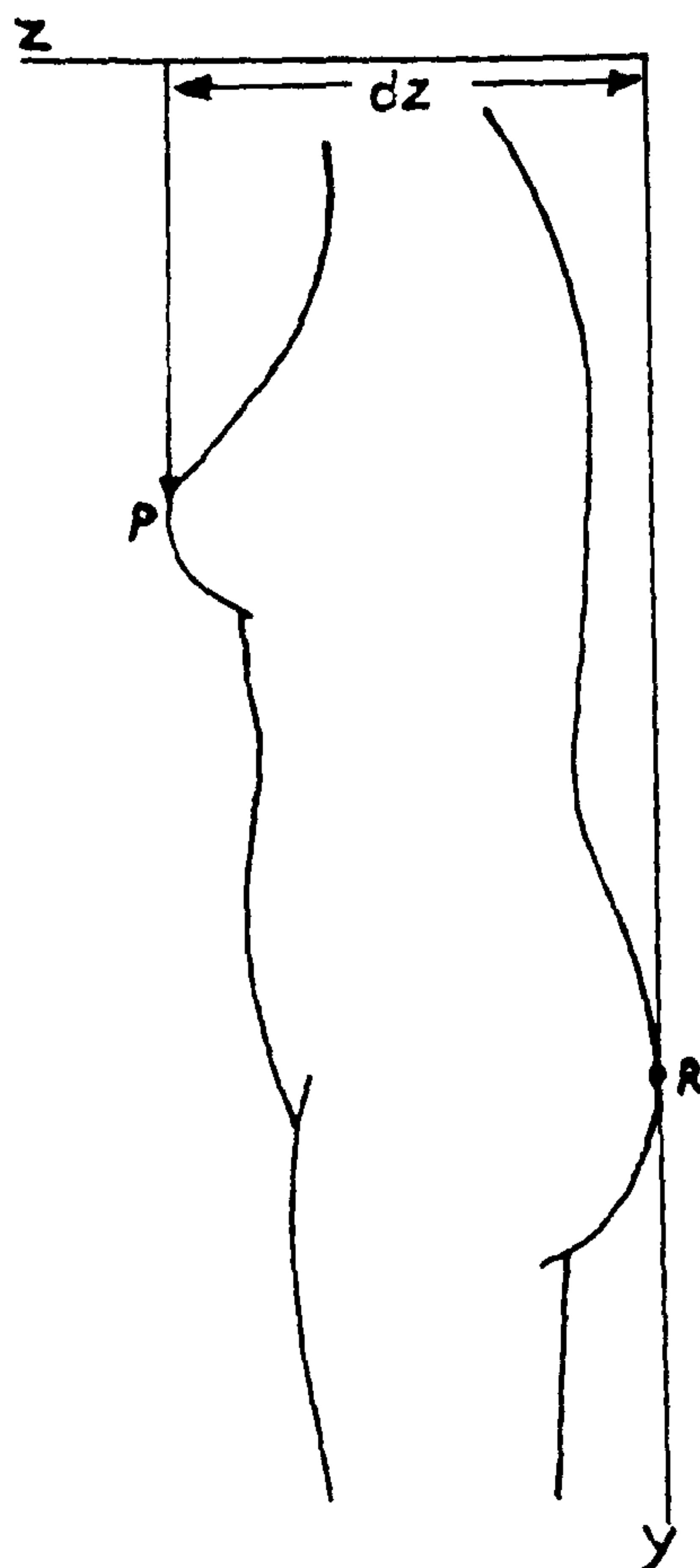
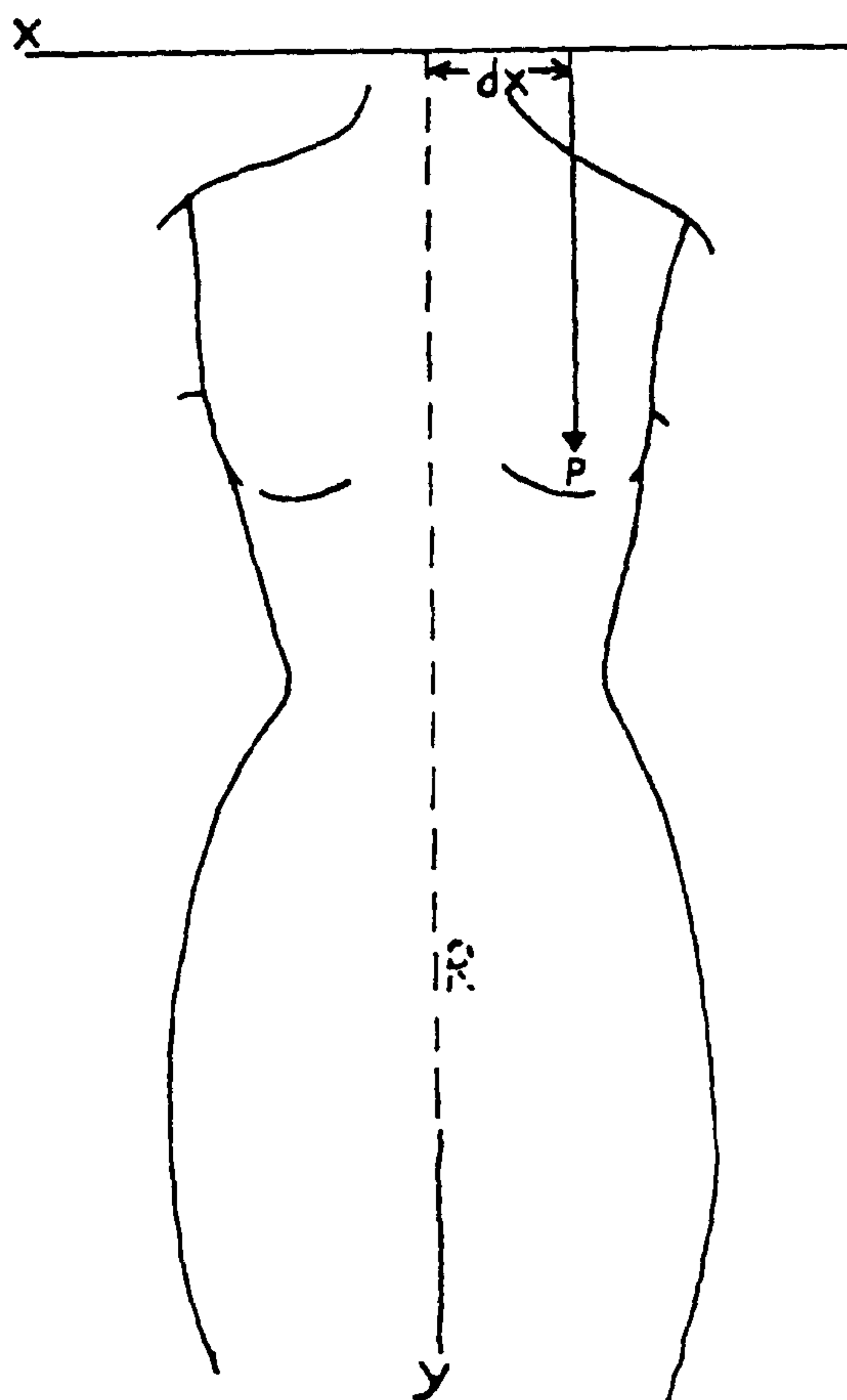
In order to measure the co-ordinates of any one of the selected points described in section 9.2, the points were first marked to locate their exact position on the body. The measurements were then obtained using either of the techniques:

9.3.1 Technique A

The 'depth' bar (D) and the sleeve accommodating the plumb line (D₁) are moved to place the plumb line exactly above the location of the point to be measured. The plumb line is then lowered to touch the point, and when in position the sleeve (D₁) and the plumb line are tightened onto the depth bar (D). Once the plumb line position is fixed, the measurements of the horizontal bar (C) and the 'depth' bar (D) are read off the frame, thus obtaining the x and z co-ordinates (see Fig. 37A). In order to obtain the y dimension co-ordinates, the sleeve (D₁) carrying the plumb line is moved back to touch the y dimension bar (B). Thus, when the plumb line is hanging vertically and parallel to the vertical bar (B), the y dimension co-ordinate may be read off the scale on bar (B). (See Fig.37B).

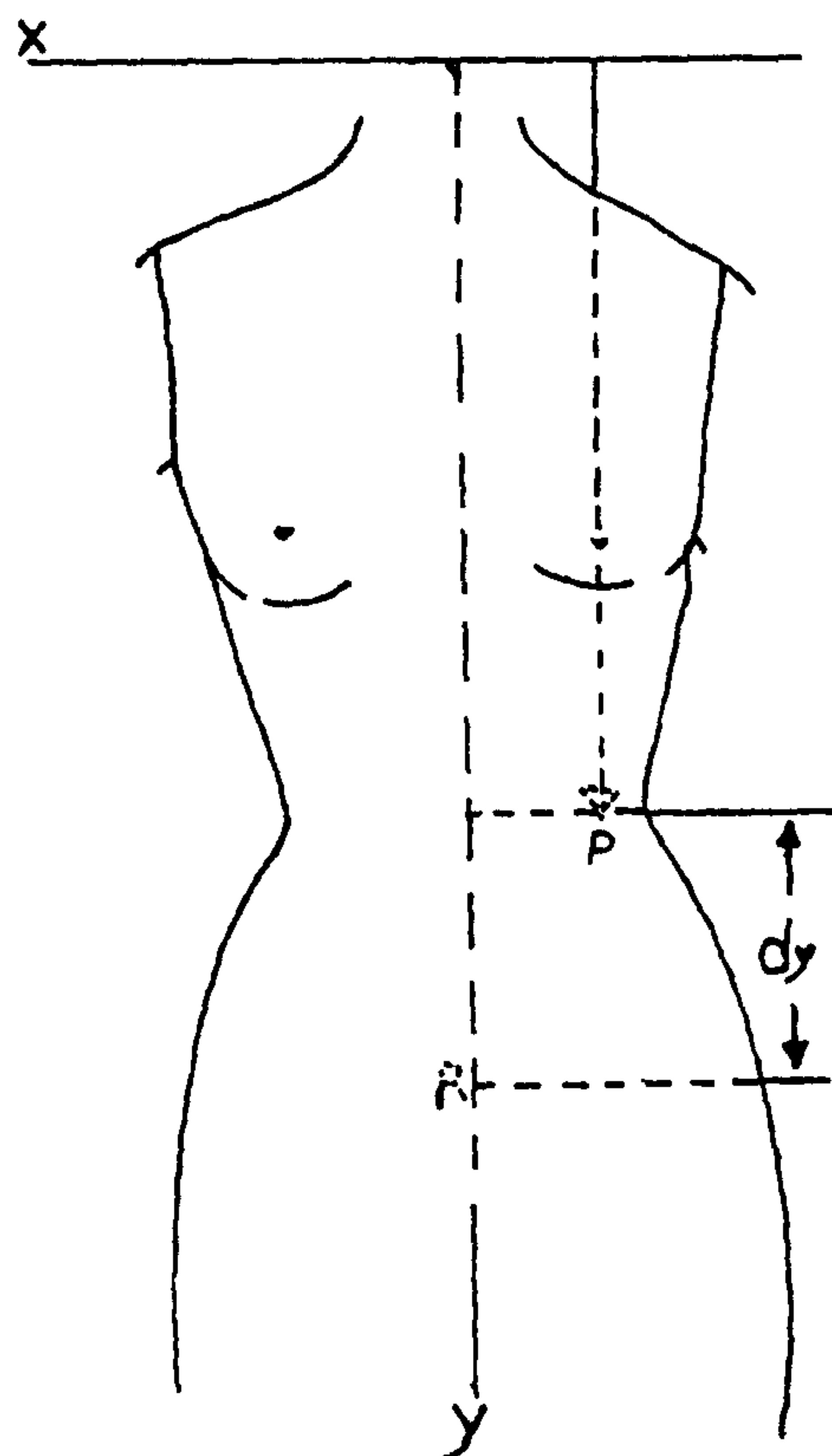
9.3.2 Technique B

A slightly different procedure is adopted to measure these points located on the body where their co-ordinates cannot be obtained using Technique A. These points are situated in such positions that other and more prominent parts of the body do not allow the plumb line to locate their exact position (eg. under arm point, mid-centre waist point etc.).



A

- R = Reference point
 p = Measuring point
 dx = Distance of p from R on
 X dimension.
 dz = Distance of p from R on
 Z dimension.
 dy = Distance of p from R on
 Y dimension.



B

MEASURING METHOD TECHNIQUE A

FIG. 37

To measure these points, the plumb line is lowered and fixed outside the exact position of the point, but on the same horizontal level as the point to be measured. This is commonly achieved by choosing to measure as the previous point, a point on the same horizontal level, which may be measured directly by Technique A. The plumb line is then already at the correct level for the y dimension co-ordinate, and by sliding bar (D) along bar (C), the plumb line can be located directly in front of the point to be measured, and the accuracy of the horizontal measurement is then ensured. If there is a difference between the two horizontal levels of two points measured one after another, then the vertical measurement from the base (A) will reveal the horizontal level that needs to be applied. Once the plumb line position is fixed, the measurement of the horizontal bar (C) may be read off the frame, thus obtaining the x dimension co-ordinate. In order to obtain the z dimension co-ordinate, the measurement d of the 'depth' bar (D) is read off the frame and the distance d₁ between the plumb line and the exact position of the point A may be measured by a tape measure. (See Fig. 38).

In order to obtain the z dimension co-ordinate, the following formula can be used:

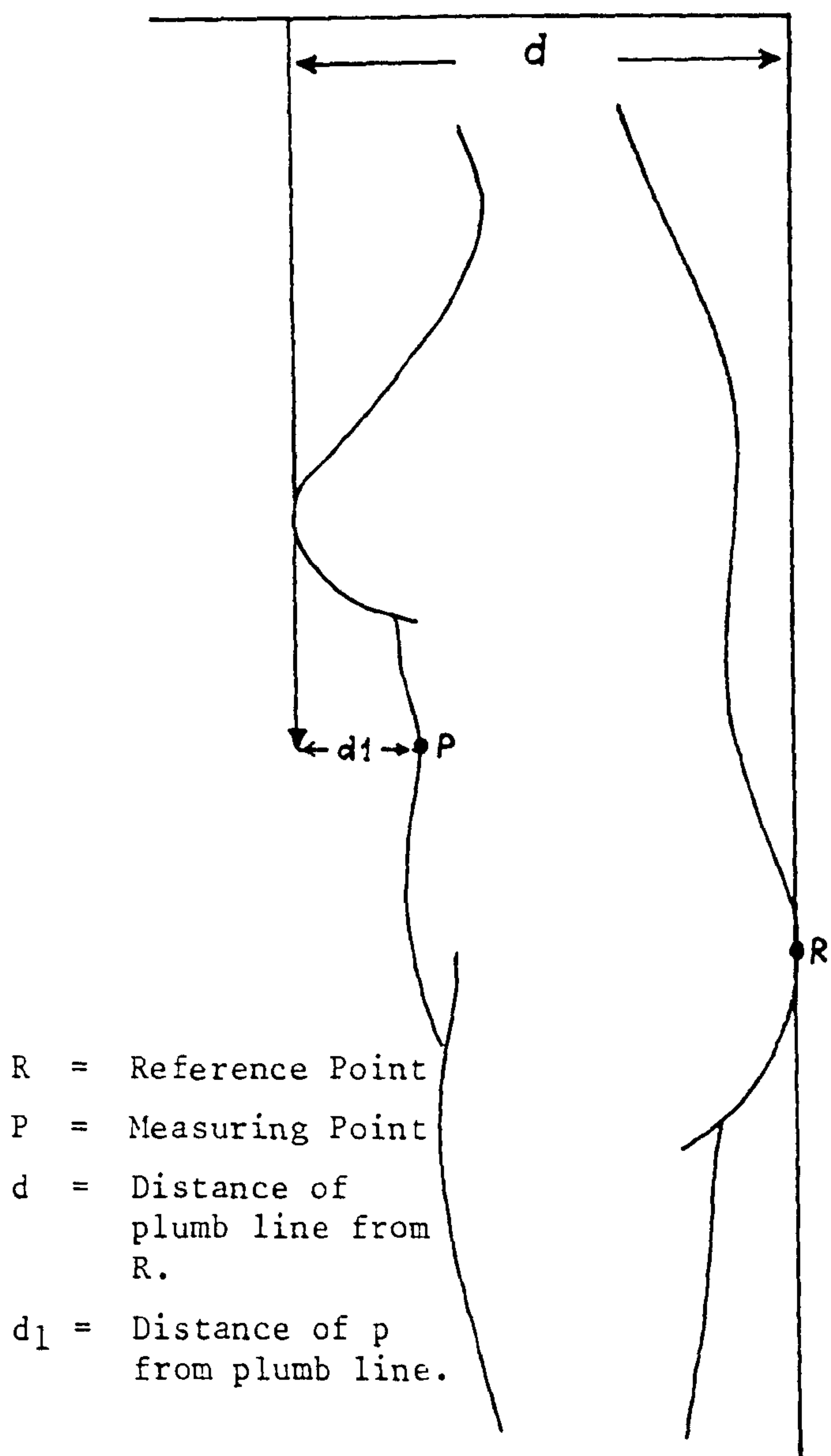
$$z_p = d - d_1 \quad (9.3.2.1)$$

where

z_p = z dimension of point p

d = the distance between the plumb line and the reference point R.

d₁ = the distance between the plumb line and the exact position of point p.



- R = Reference Point
 P = Measuring Point
 d = Distance of
 plumb line from
 R .
 d_1 = Distance of p
 from plumb line.

MEASURING METHOD TECHNIQUE B

FIG. 38

To obtain the y dimension co-ordinate, the method is precisely the same as for Technique A.

By using either Technique A or B on the measuring frame, the three-dimensional co-ordinates of all the points mentioned in section 9.2 may be accurately determined.

9.4 THE DEVELOPMENT OF A METHOD FOR DRAFTING PATTERNS

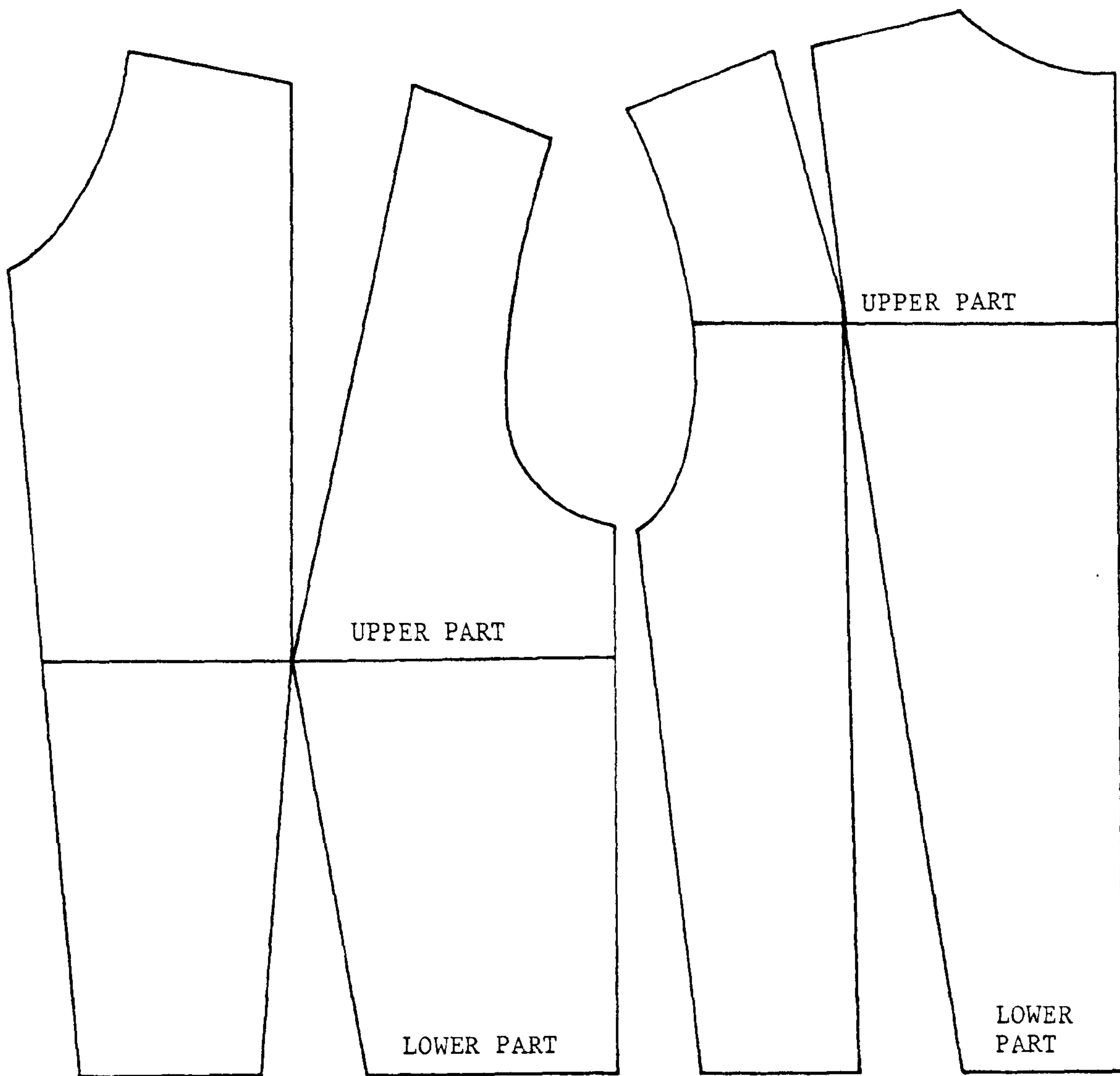
9.4.1 Location of Dart

As has already been shown, a dart is needed to be inserted in a pattern to allow a flat surface to be converted into a three-dimensional 'shell'. It is obvious that upon establishing the angle of the dart needed, the dart may then be divided into any number of smaller darts radiating from the apex point to any desired position on the body. That being the case, before an attempt is made to develop a method for drafting patterns, the exact placement of the dart should be established.

In practice, in the case of the work described in this thesis, the dart was divided into two; one radiating from the apex point on each panel to the centre shoulder point, the other to the centre waist point, thus establishing shoulder-bust and waist-bust darts for each panel.

Further observation revealed that to get the most satisfactory fit and garment appearance, it was desirable for the angle of the divided darts to be such that, the upper and lower part of the panel subtended an angle of 180° at the apex point. Thus, each panel of the body has been divided into two horizontal sections resulting in upper and lower parts for each panel. (See Fig. 39).

It is obvious that the summation of all the angles radiating around the apex point of each part (including the angle of dart located at this part), should be equal to 180° . Thus, if the total of all the angles (excluding the angle of dart) is less than 180° , the remainder is the angle of dart needed to fit that part of the body.



DIVISION OF BODY PANELS INTO UPPER AND LOWER PARTS

FIG. 39

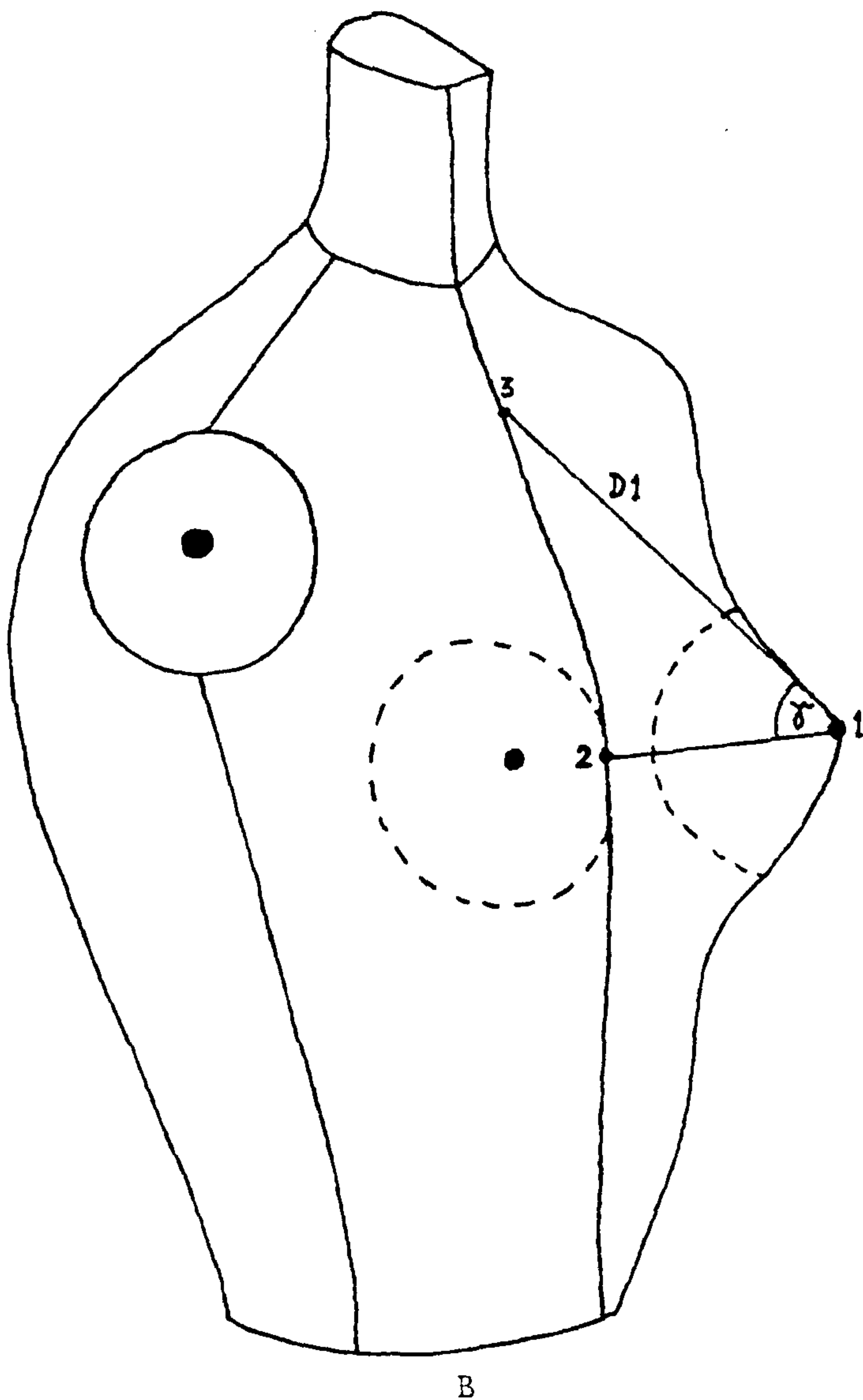
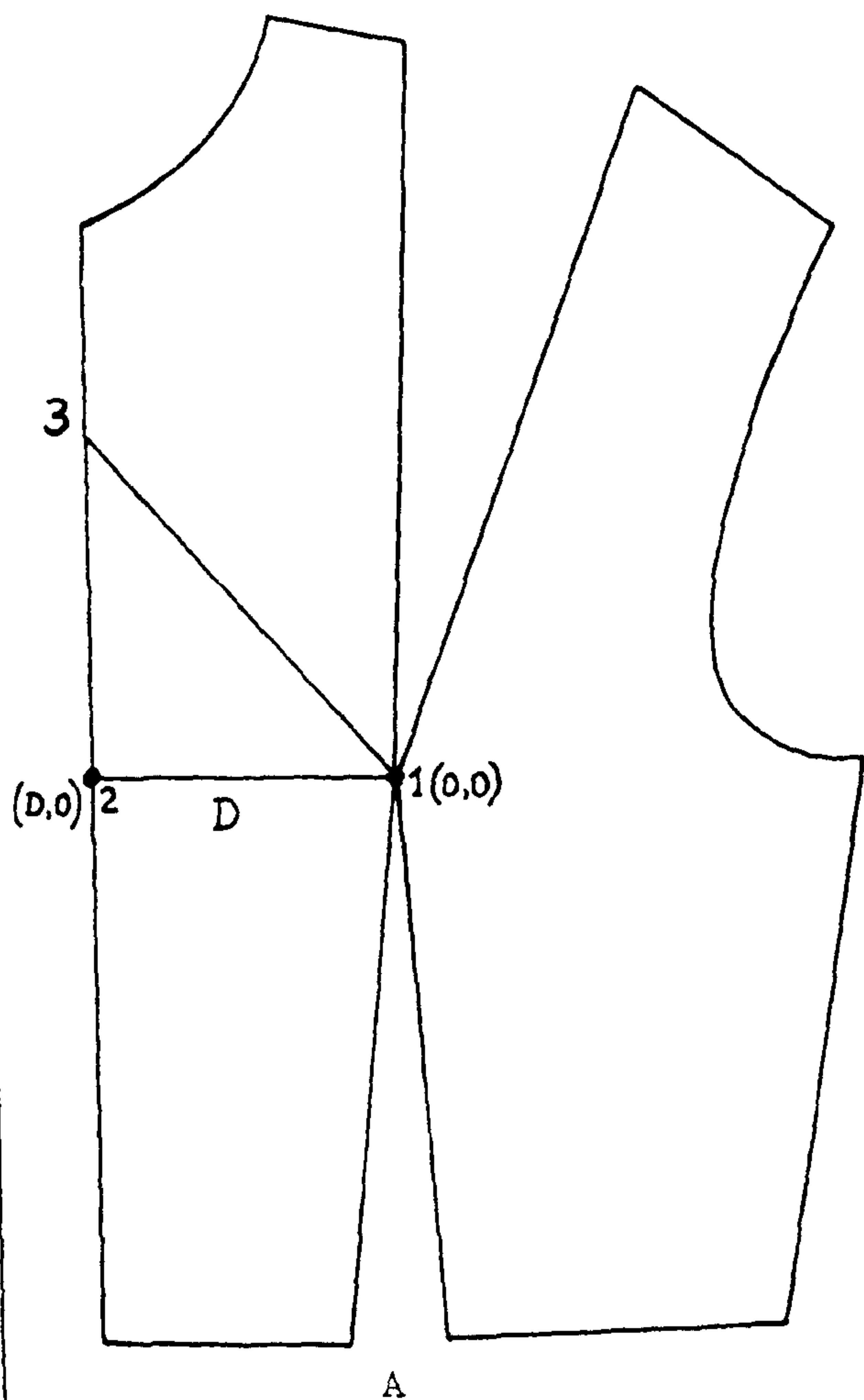
The angle of dart needed to be inserted into the other part of the same panel is obtained in the same way. This will result in an accurate location and division of the overall dart which will ensure a balanced and satisfactorily fitted garment.

9.4.2 Method of obtaining two-dimensional co-ordinates for drafting patterns

As described in the previous chapter, the new measuring frame allows the measurement of the three-dimensional co-ordinates of the crucial shaping points of the human body. For the production of patterns, this information needs to be transferred into the appropriate two-dimensional co-ordinates, giving the representation of these points at the correct distances and angles from the apex point in the two-dimensional plane of the fabric from which the garment is to be constructed. This may be achieved in the following way:

If the apex point of each panel of the body is assumed to be the origin, the co-ordinate of this point in the two-dimensional plane is 0, 0. (See Fig.40A). When point No. 2 on the body is to be calculated, its location on the two-dimensional pattern is determined by D (the distance between point No. 2 and the apex point) and since this may be shown horizontally on the pattern the co-ordinate of this point will be D, 0. (See Fig. 40B).

It may be observed from Fig. 40 that the location of point No. 3 no longer lies horizontally with the apex point. Hence, since from the three-dimensional measurements it is known that the angle between points 2, 3 and the apex point is given by γ , and that D_1 is the distance between point No. 3 and the apex point, this point may be accurately determined on the two-dimensional pattern.



ESTABLISHING THE TWO-DIMENSIONAL CO-ORDINATES FOR POINTS No. 1, 2, & 3

FIG. 40

Progressively in this way, the exact location of each of the crucial shaping points on the two-dimensional plane can be assessed.

Mathematically, this operation may be described as follows:
using the following formulae:

$$X(I) = D(N) \times \cos \sum_{i=0}^N \gamma(i) \quad (9.4.1)$$

$$Y(I) = D(N) \times \sin \sum_{i=0}^N \gamma(i) \quad (9.4.2)$$

Where,

I = point number, and $I \geq 2$
 N = $I-2$

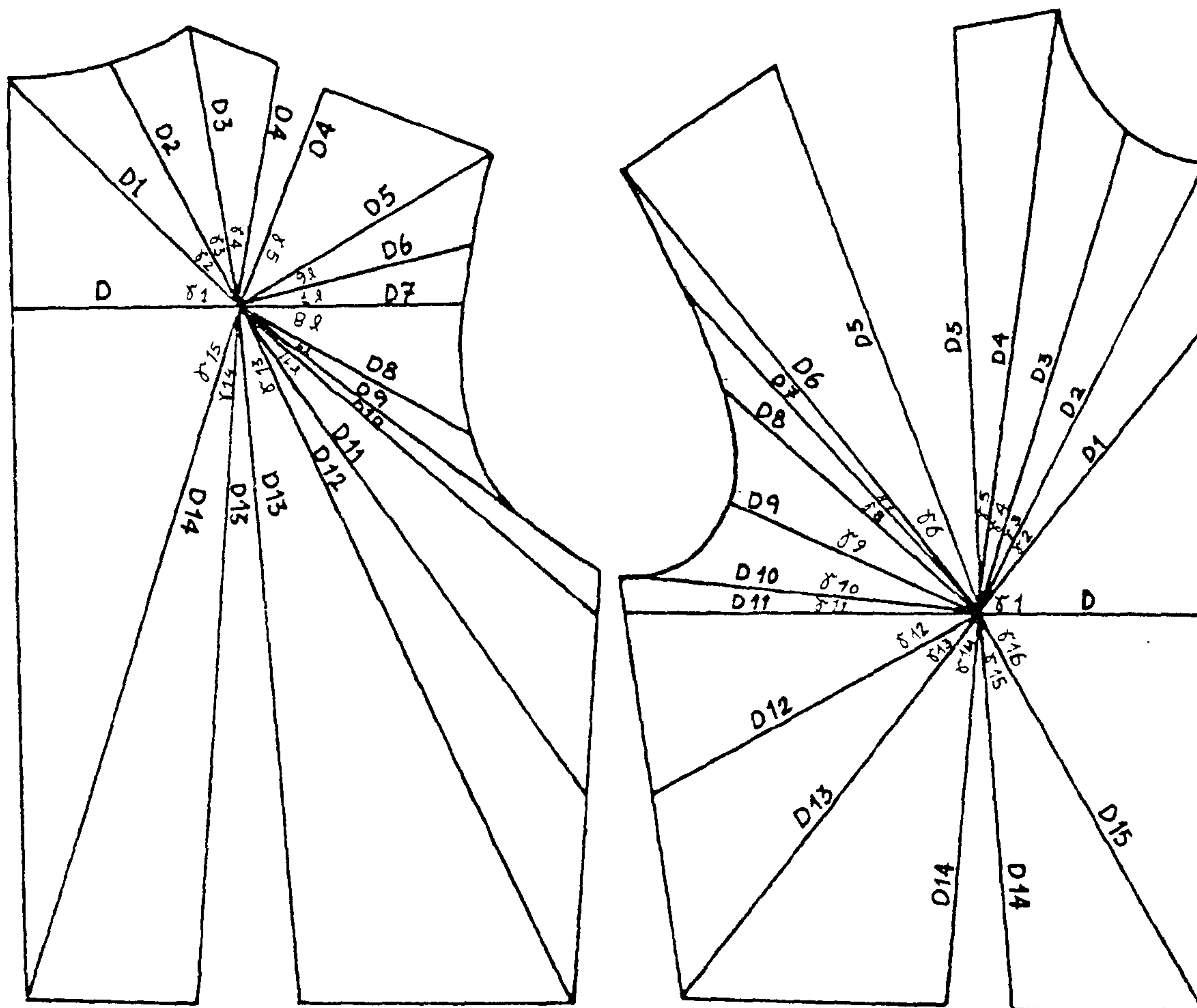
$X(I)$ = co-ordinates of point No. I
 $Y(I)$

$D(N)$ = distance between apex point and point No. I

$\sum_{i=0}^N \gamma(i)$ = the sum of the angles radiating around the
apex point

$\gamma(0) = 0$

In this way, the exact location of each point on the two-dimensional pattern can be obtained. The only additional feature, is that the required angle of dart (as determined by the method described in the previous section) has to be inserted in the correct place on the two-dimensional flat pattern. (i.e. at mid-shoulder and mid-waist points on each panel). This is shown in Fig. 41 where the distances $D-D_n$ and the angle $\gamma_1 - \gamma_n$ (including the angle of dart located for each part of each panel) are illustrated.



ESTABLISHING THE TWO-DIMENSIONAL CO-ORDINATES FOR THE CRUCIAL SHAPING POINTS

FIG. 41

Thus, each panel may be produced in its correct two-dimensional shape, so that when sewn together, it should provide a garment which will fit the measured body perfectly.

CHAPTER TEN

THE DEVELOPMENT OF A COMPUTER SYSTEM TO
PRODUCE WELL SHAPED PATTERN PIECES

The craft based clothing industry has always been labour intensive and this being the case, it is logical to conclude that labour is probably the biggest asset in this industry.

A study reported in 1962 (43) revealed that most employers admitted that they suffered from labour problems such as difficulty in attracting labour, poor quality of labour available, high training costs, labour turn over and absenteeism which resulted in inefficient labour utilisation and high production costs. It has been shown (44) that the clothing industry has a declining labour force, and in the Textile Institute review (of 1973) (45) it has been commented that the force had declined by more than 20% between the years 1961 - 1968 and was expected to continue to fall by 2% per annum over the next ten years. Furthermore, it has been shown that the basic problem of the clothing industry in all countries whose production costs are high is to continue to satisfy the demand for clothing using the available labour force and at the same time maintaining the relatively low prices of the finished garments.

It has been mentioned (46) that the rate at which the apparel industries in these countries is declining and the low cost imports are increasing is such that there is a danger that the size of the industry in some of these countries could be reduced to the point where viability is threatened. At the same time, in the 70's, the industry has been moving towards mechanisation to such a degree that by becoming capital intensive the labour costs no longer critically affect the cost of production. It began to lose its craft attitude and aspect and began to emerge as an engineering based construction industry whose future was more likely to be capital rather than labour intensive.

This conversion of the industry from a labour intensive to a capital intensive paved the way for a new development in the industry using high technology and mechanisation and notably, computer technology. The 1970's was the period when the application of these techniques in the clothing industry became a common feature.

10.2 COMPUTER APPLICATIONS IN PATTERN PRODUCTION

10.2.1 Application in grading and marker making

The earliest application of computers in the clothing industry was two systems for grading and marker making, developed and introduced by two American firms CAMSCO and HUGHES. Both systems offered to the manufacturers the possibility of automating the processes of grading and marker making, which are very skilled and time consuming jobs.

When these were processed by computer, the time saving was considerable and if accurately applied, could result in more accurate cuts leaving the cutting room. However, it is important to realise that this application relied entirely upon traditional methods to determine the required pattern shapes and the computer was only used to apply these standard techniques more easily and reliably.

10.2.2 Recent commercial attempts to apply computer techniques to produce patterns

The development of systems to produce block patterns by computer has again been governed by the two big firms: CAMSCO developed a system for the ready-to-wear market and HUGHES developed a system for the made-to-measure market.

The system developed to cater for the ready-to-wear market is known as the 'Pattern Design System' (P.D.S.). The P.D.S. is a computer based interactive graphics system which automates the process of developing the production pattern from the block pattern, and which may also be used as an alteration tool for changing the shape of any production pattern already in the system.

The system uses an information bank, which consists of a collection of block patterns which have been fed into the system using a digitiser. Once the block patterns have been digitised and fed into the system they can be divided into pieces consisting of parts of a single block pattern or parts of different block patterns for the use of constructing new production patterns.

It is apparent however, that although the system can be regarded as a very sophisticated one, it still has to use a block pattern which has been developed and produced by the traditional trial and error method. This has already been shown to be inaccurate and will not ensure more accurate pattern pieces than those obtained traditionally.

The system catering for the made-to-measure market had been developed in particular for made-to-measure services offered by a large multiple tailoring organisation. The system produces completely individual patterns and allows for any alterations needed to be carried out. A salesman in a high street shop takes the customer's measurements which are fed into the system for preliminary checks. The computer then studies the customer's measurements and rejects any which appear to be impossible according to restrictions already filed in its memory. If the measurements are found to be valid, they are compared with the standard measurements for the style to be chosen for the same chest size.

When a change is required, the computer identifies allowances for that and specifies the increments needed on every part of the pattern according to a set of instructions already filed in its memory. Any adjustments for particular figurations such as rounded backs, etc., are then carried out and the final product is a full scale pattern to fit the customer's measurements.

Although the system has been proved to save in cloth and manpower and has been claimed to be a success (47), it must be appreciated that it still requires the measurements to be taken by the salesman in the shop and that the block patterns filed into the computer for comparison purposes, are made by the pattern cutter who uses the traditional method shown to be inaccurate if a well fitted garment is required.

10.3 THE PATTERN PRODUCTION SYSTEM

10.3.1 Introduction

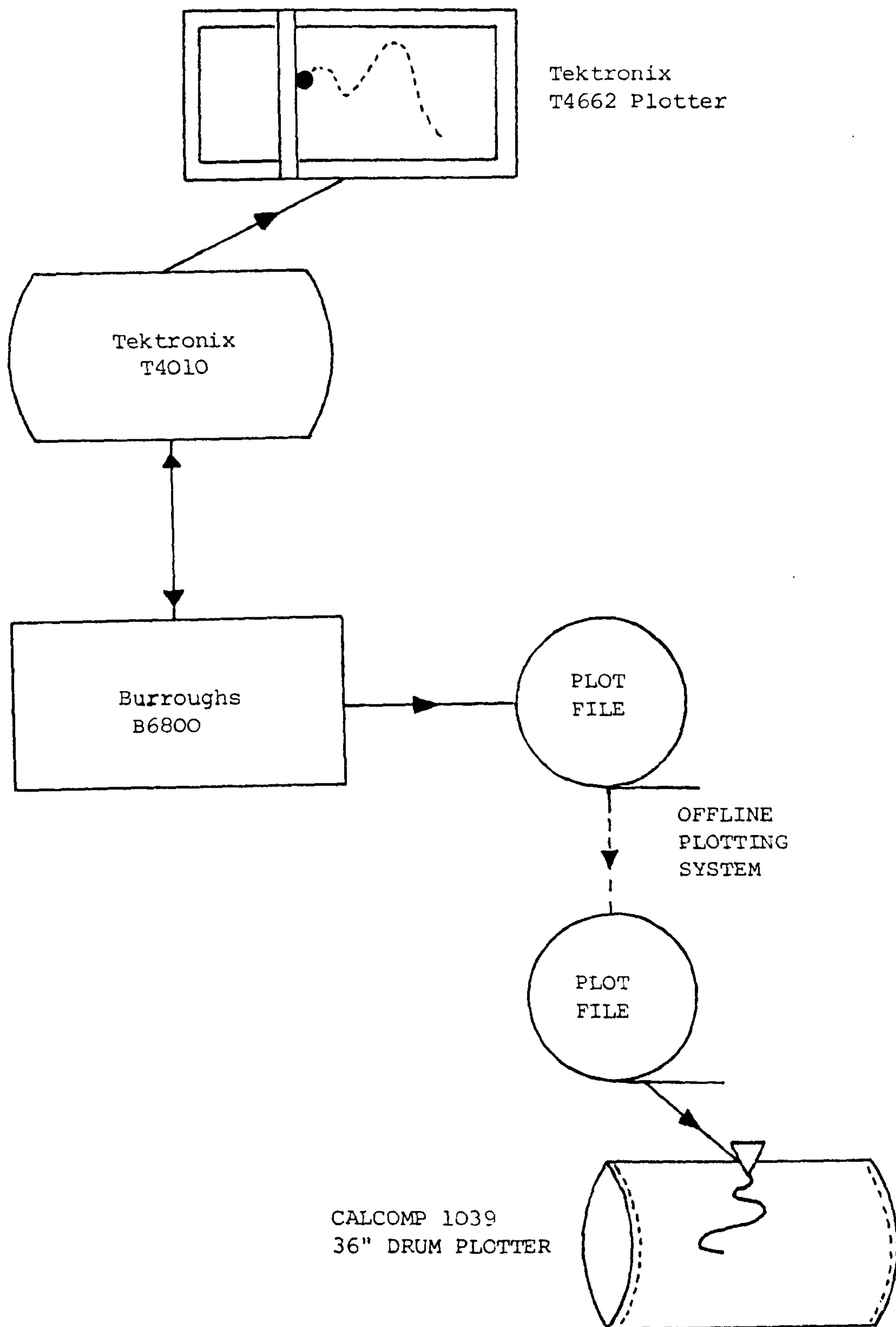
In contrast with all these earlier attempts to integrate computer techniques into the industry, the application developed in the course of the work described in this thesis, was to use the computer so that, by feeding the three-dimensional co-ordinates of the human body into it, the computer would accurately establish the required two-dimensional patterns and plot out the appropriate pattern shapes. In this way, the proposed new method for obtaining garments of satisfactory fit, would not require any drafting skills or mathematical analysis, and computers already established in the industry, could be used to supply for each set of measurements, patterns of the correct dimensions and accurate shape.

This pattern production system would produce either a skin or block pattern; patterns incorporating style features would require additional design details which might be added at a later stage.

The pattern production system performs the following functions:

- (i) Reads the already stored three-dimensional body measurements.
- (ii) Establishes the size and shape of the darts needed to be inserted into the pattern to convert the flat fabric into a three-dimensional garment.
- (iii) Calculates and establishes the two-dimensional co-ordinates needed in order to plot the pattern.
- (iv) Plots, upon request, either full or scaled size pattern pieces.

The pattern production system comprises of a digital computer, a graphics display terminal, a keyboard and an option of two plotters for plotting either full or scaled pattern pieces. (See Fig. 42).



HARDWARE STRUCTURE OF THE PATTERN PRODUCTION SYSTEM

10.3.2 HARDWARE

10.3.2.1 The digital computer

The digital computer which was used to develop the pattern production system (P.P.S.) was the Burroughs 6700 and the upgraded Burroughs 6800 (48). The P.P.S. uses 12k of main memory.

10.3.2.2 The graphic display terminal

The graphic display terminal used to develop the pattern production system was the TEXTRONIX 4010 computer display terminal which was used as a communication link and display device between the user and the computer.

The T-4010 consists of a display section which contains the screen, keyboard and operating controls and can display the results either in alphanumeric form or in the form of graphs and pictures using the graphics plot mode of the terminal. This combination of graphic and alphanumeric display was needed if a screen view of the pattern together with the question and answers were to be viewed at the same time.

10.3.2.3 The keyboard

Attached to the graphic display terminal and an integral part of it was the keyboard device, which was the means by which the system and the pattern maker 'converse'. Messages from the computer which are displayed on the display terminal, are answered by typing on the keyboard. The answers simultaneously appear on the display terminal and when entered are then acted upon by the computer.

10.3.2.4 The plotters

Two plotters have been used as output devices to allow for hard copies to be obtained. If a full size pattern is requested, the system uses the CALCOMP model 1039 drum plotter which is 36 $\frac{1}{4}$ ins. wide, can plot either alphanumerical characters or graphic plots and can accommodate the full size scale of the required pattern.

If a small scale size of pattern is required, the system uses the TEXTRONIC 4662 which is an interactive plotter, digitally stepped and controlled. It will accept paper up to 27.9 cm x 43.2 cm (11 x 17 inches) and its maximum plotting size is 25.4 cm x 38.1 cm (10 x 15 inches).

Any required size within this range may be plotted and the scaling feature of the plotter allows the plot size to be easily adjusted. The T-4662 plotter can plot either alphanumerical characters or produce graphic plots by moving the pen across the plotting area lifting and lowering the pen to produce lines where desired.

10.3.3 SOFTWARE

10.3.3.1 Introduction

The means by which patterns are produced are determined by the software and it is this software which will be described in this section.

As already mentioned, the software was designed to read the three-dimensional body co-ordinates, process this information and produce either skin or block patterns which when sewn into a garment would satisfactorily fit the human body.

The pattern production system was divided into five sections, each containing one or more routines and each designed to solve a different function in the process of pattern production. They are as follows:

- (i) main module
- (ii) dialogue module
- (iii) calculation module
- (iv) support module
- (v) drawing and plotting module

The software which was designed, written and developed by the author of this work, does include a number of drawing and plotting routines which were extracted from a Graphical Input/Output Fortran package. This package (the GINO-F), is a powerful set of graphic routines which can plot almost any shape required, either in two or three-dimensions. Its most important feature is the fact that any part of it may be added to any existing program simply by incorporating the routine required within that program.

As has already been mentioned, the software was designed to produce patterns according to pre-stored three-dimensional body co-ordinates.

Thus, before the software can be run, the three-dimensional co-ordinates have to be measured and stored in the computer's memory. The data was entered via the keyboard attached to the graphics display terminal and stored on disc as a data file.

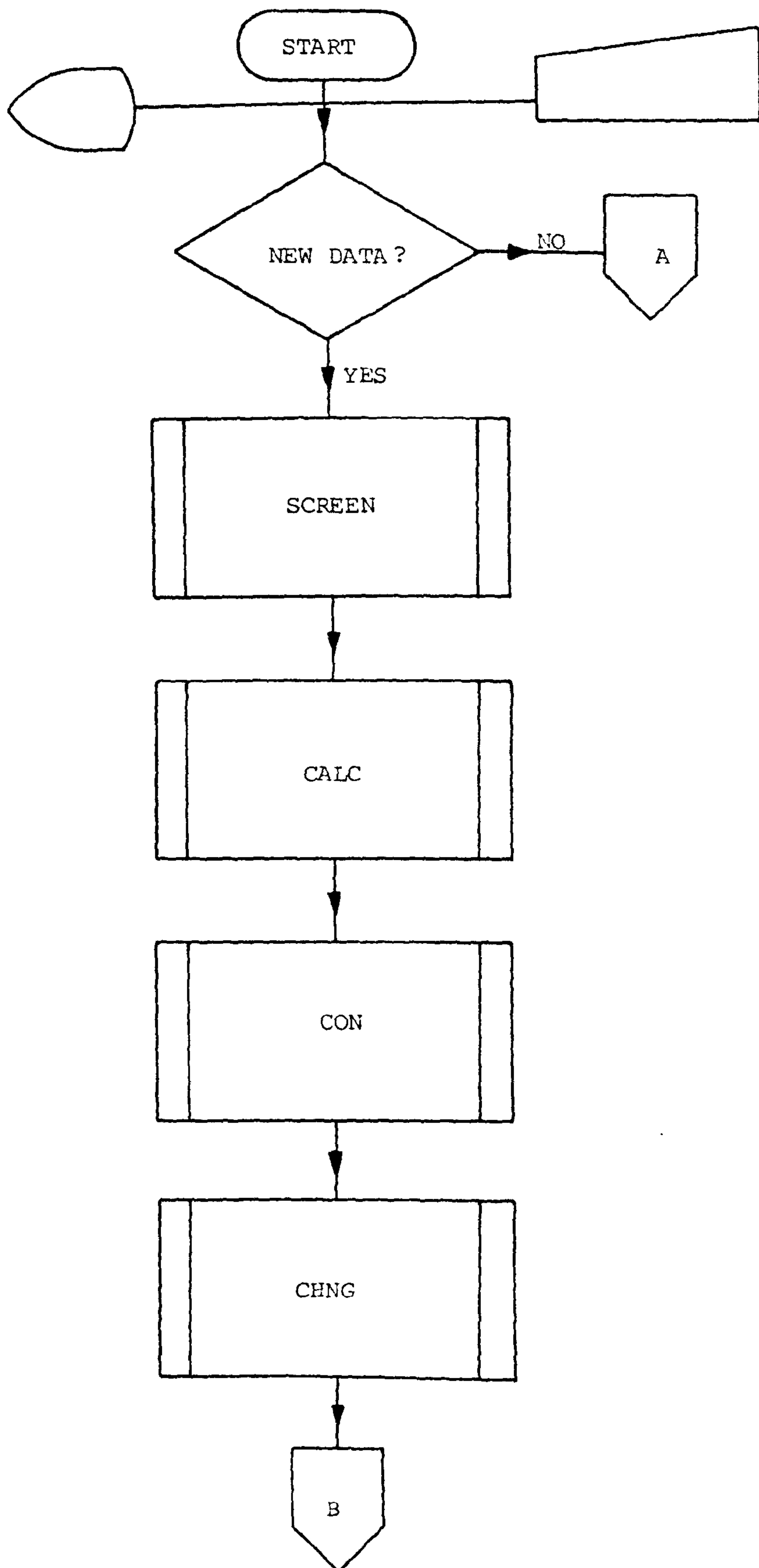
10.3.3.2 Main Module

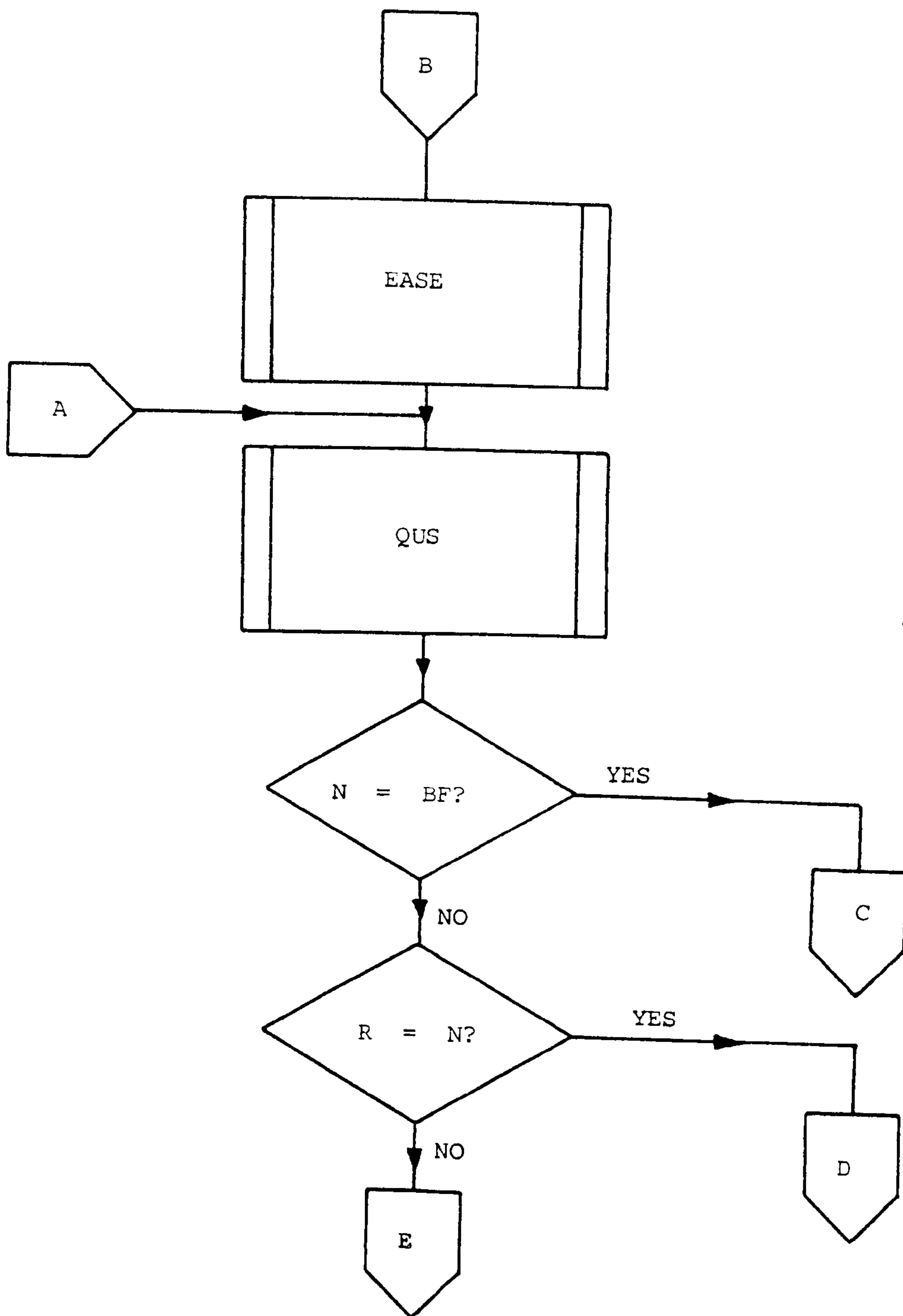
This section was designed to control all the other four sections and to direct the operation of each of the routines and sub-routines provided by the software. It consists mainly of a set of 'call routine' statements which pass control to the appropriate routines according to the answers typed in, and a number of routines to actually produce some of the patterns available. It also provides an introductory message and a short dialogue which was designed to determine:

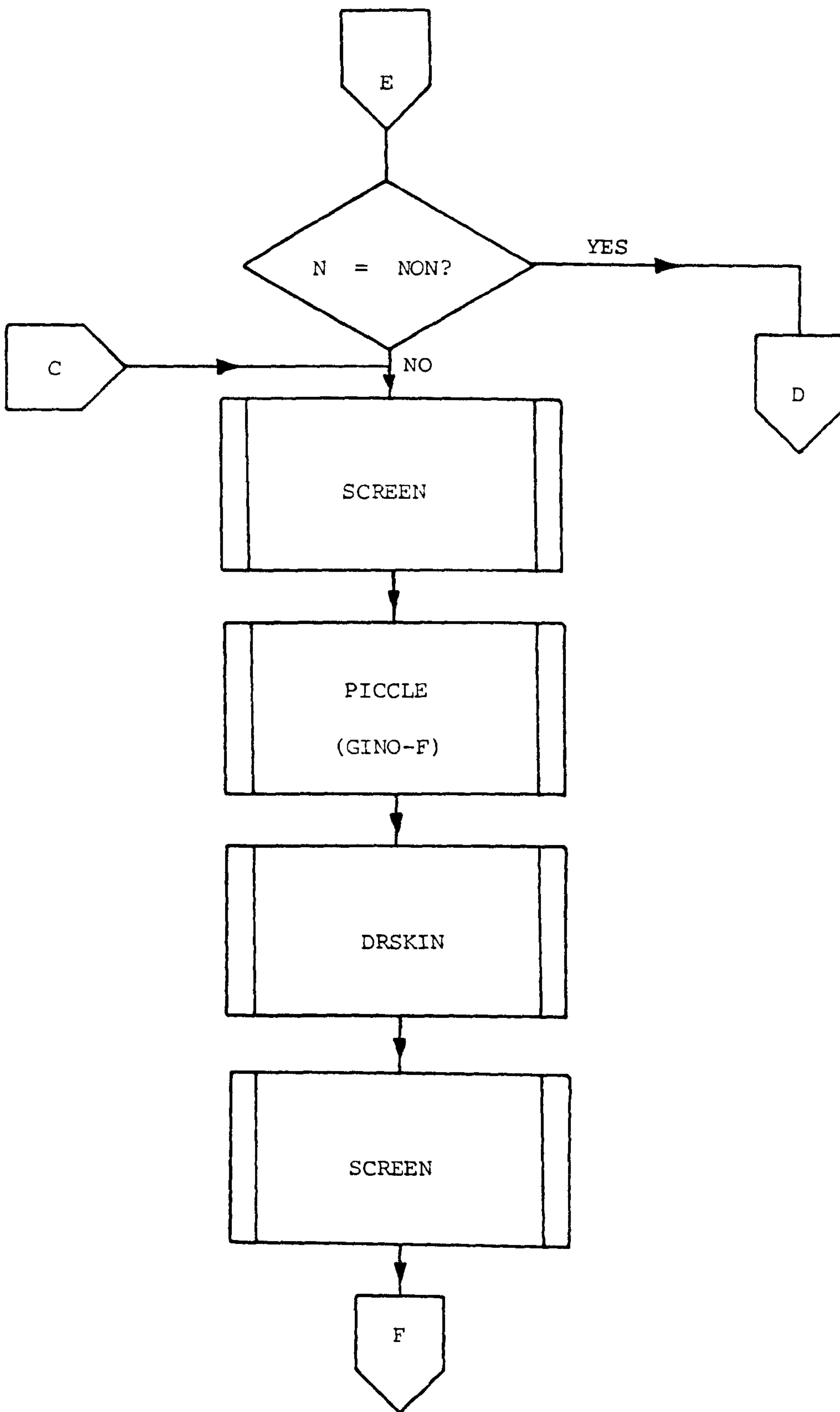
- (i) whether new three-dimensional body measurements were fed into the system and if so, to process it and establish the new information.
- (ii) whether a hard copy of the pattern produced is needed, and if so to pass control to the appropriate routines.
- (iii) whether the pattern produced was the last one required and if so to end the running of the program.

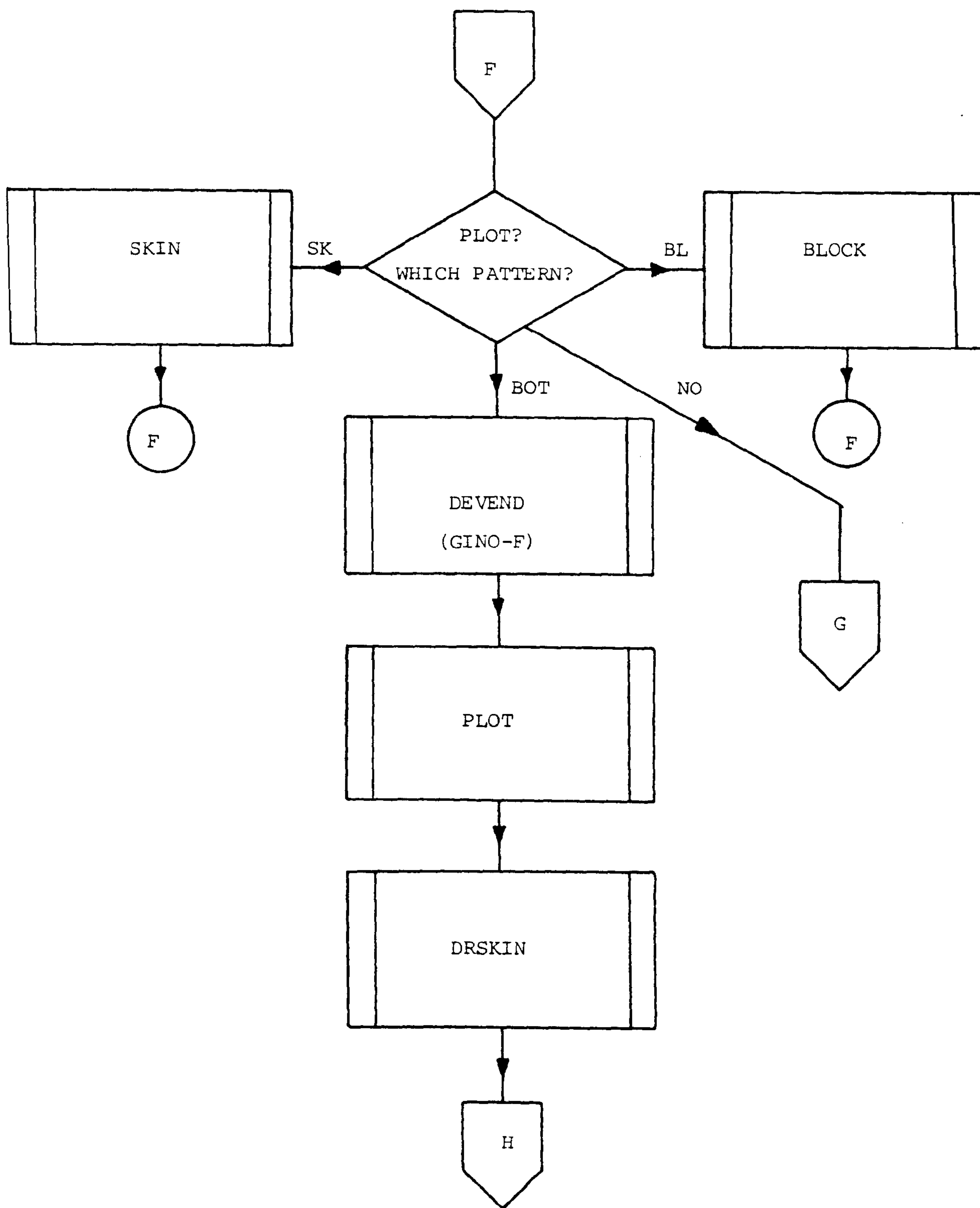
The structure of this section is illustrated by the following flow chart.

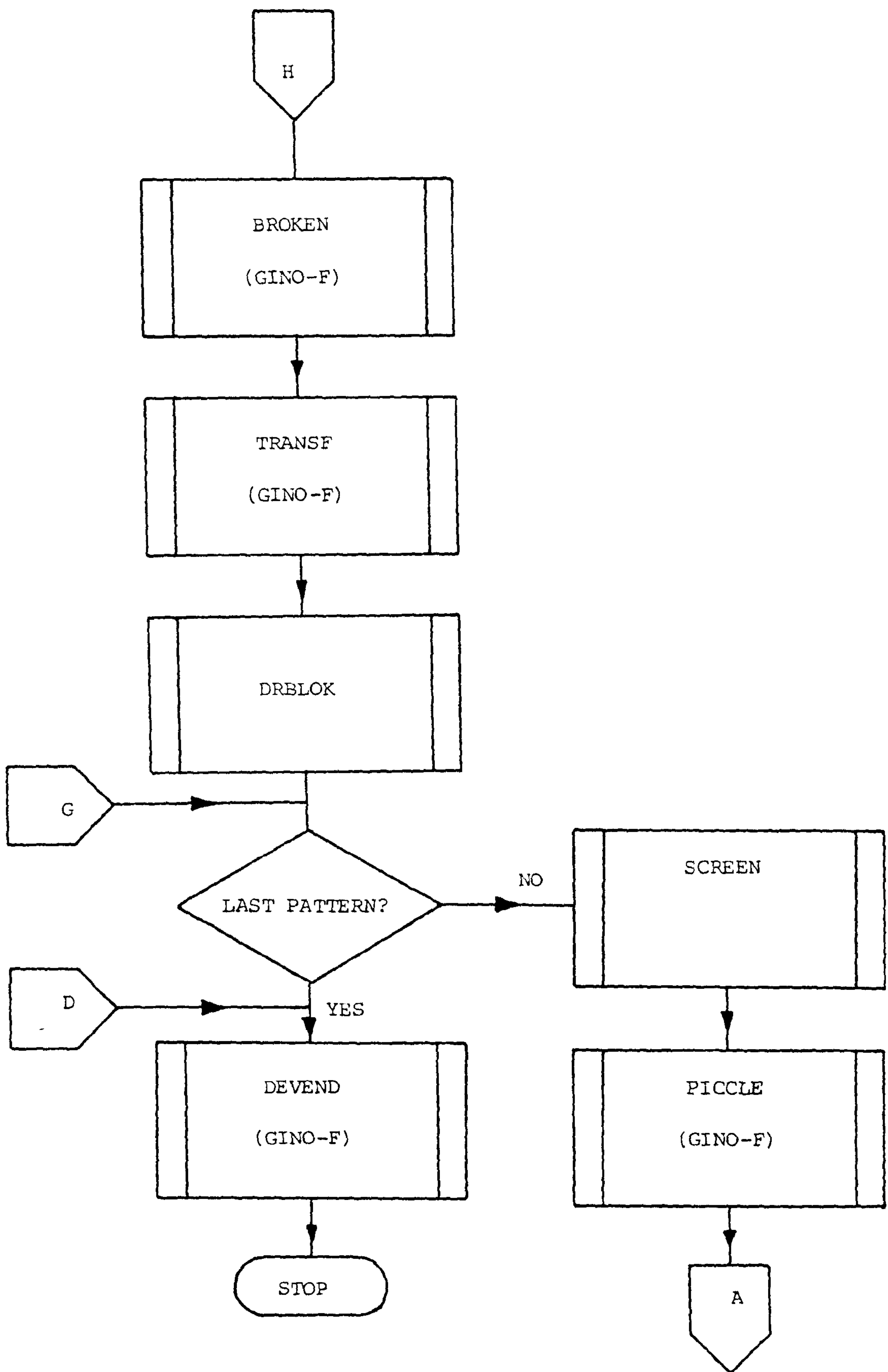
FLOW-CHART 1 : MAIN MODULE











10.3.3.3 Dialogue Module

This routine was designed as a dialogue which involves the use of the following routines:

(i) The QUS Routine

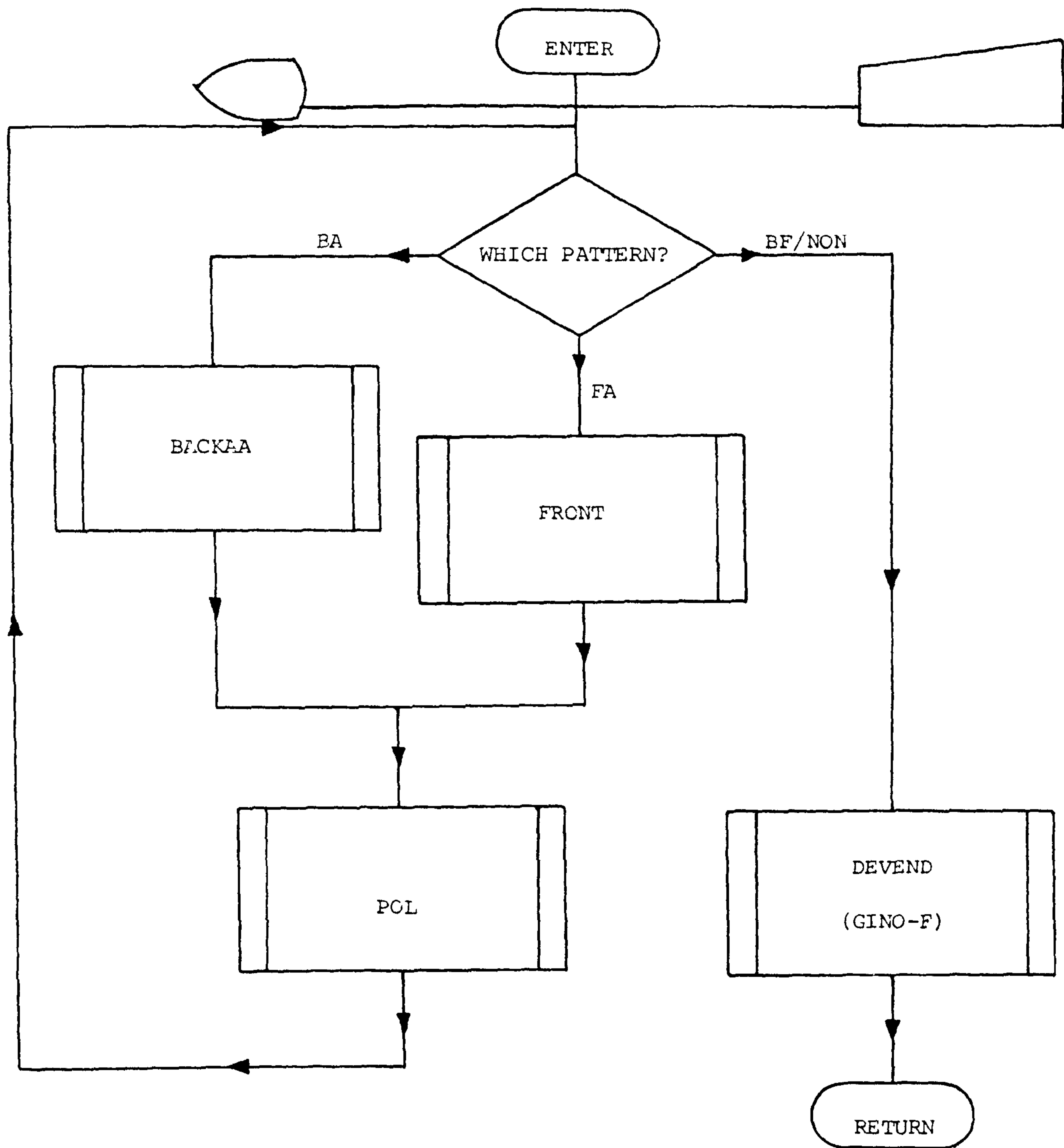
This routine was designed to establish which of the options provided by the system are to be produced next; according to the answer typed in the routine passes control to the relevant sub-routine to produce the pattern required.

(ii) The POL Routine

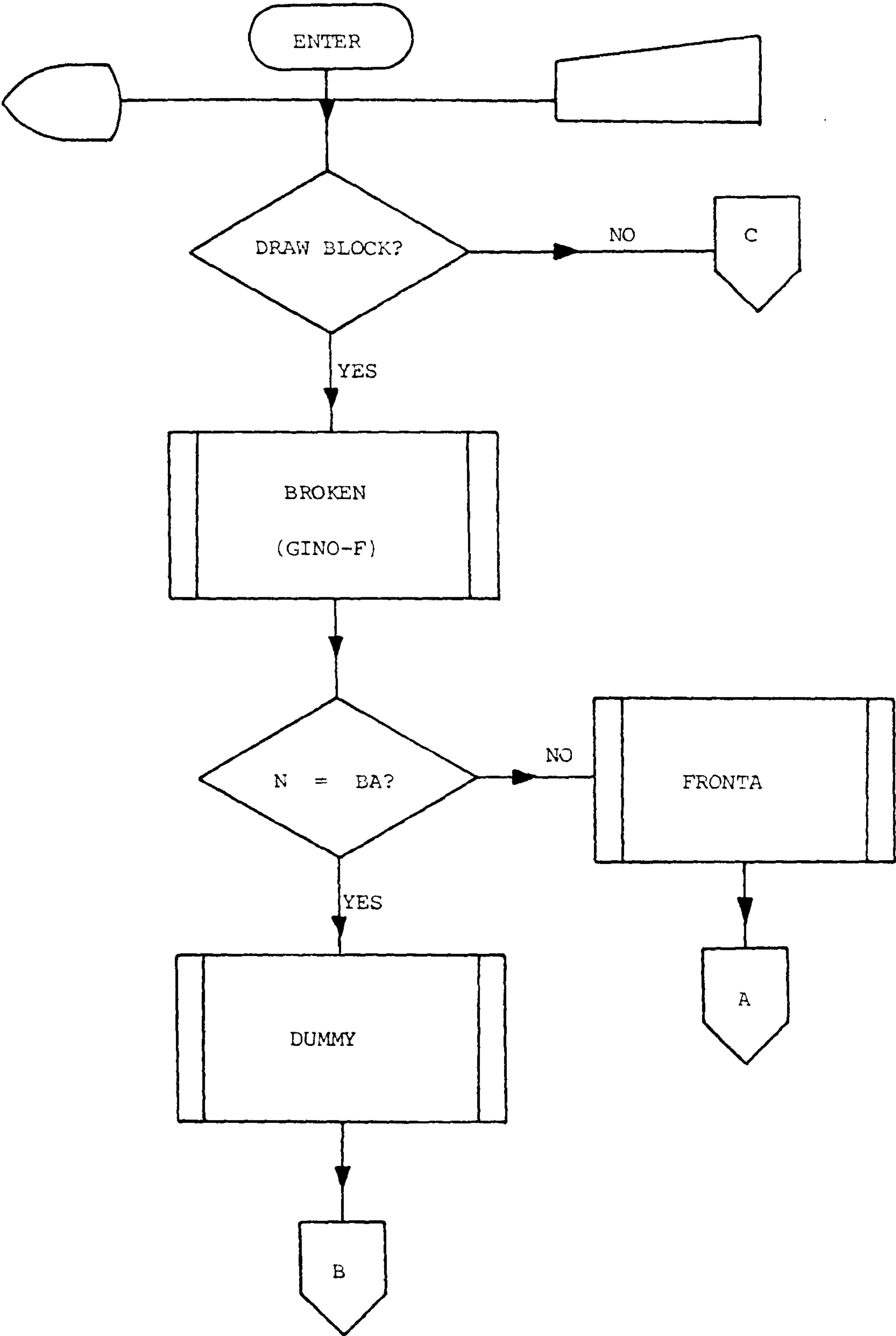
After the relevant sub-routines have produced the appropriate pattern and have drawn it on the screen, the POL routine is called to establish whether a block pattern is required, and if so, this routine passes control to the relevant sub-routines which will superimpose it on the skin pattern already on the screen.

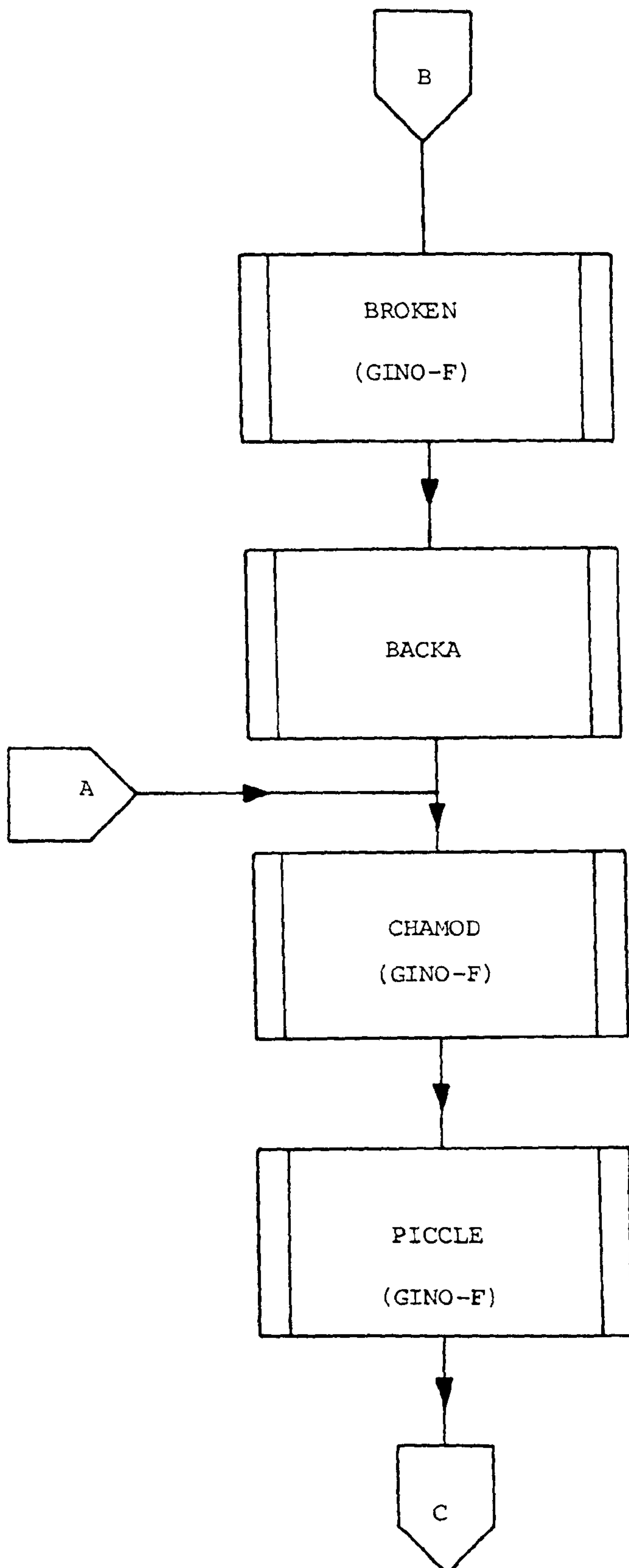
If a block pattern is not requested, the routine will print a message on the screen asking whether a hard copy of the skin pattern is required, and depending upon the answer provided, the routine will either pass control to the sub-routine, which will plot the pattern on the plotter, or will return control to the QUS routine. The structures of these routines are illustrated by the following flow charts.

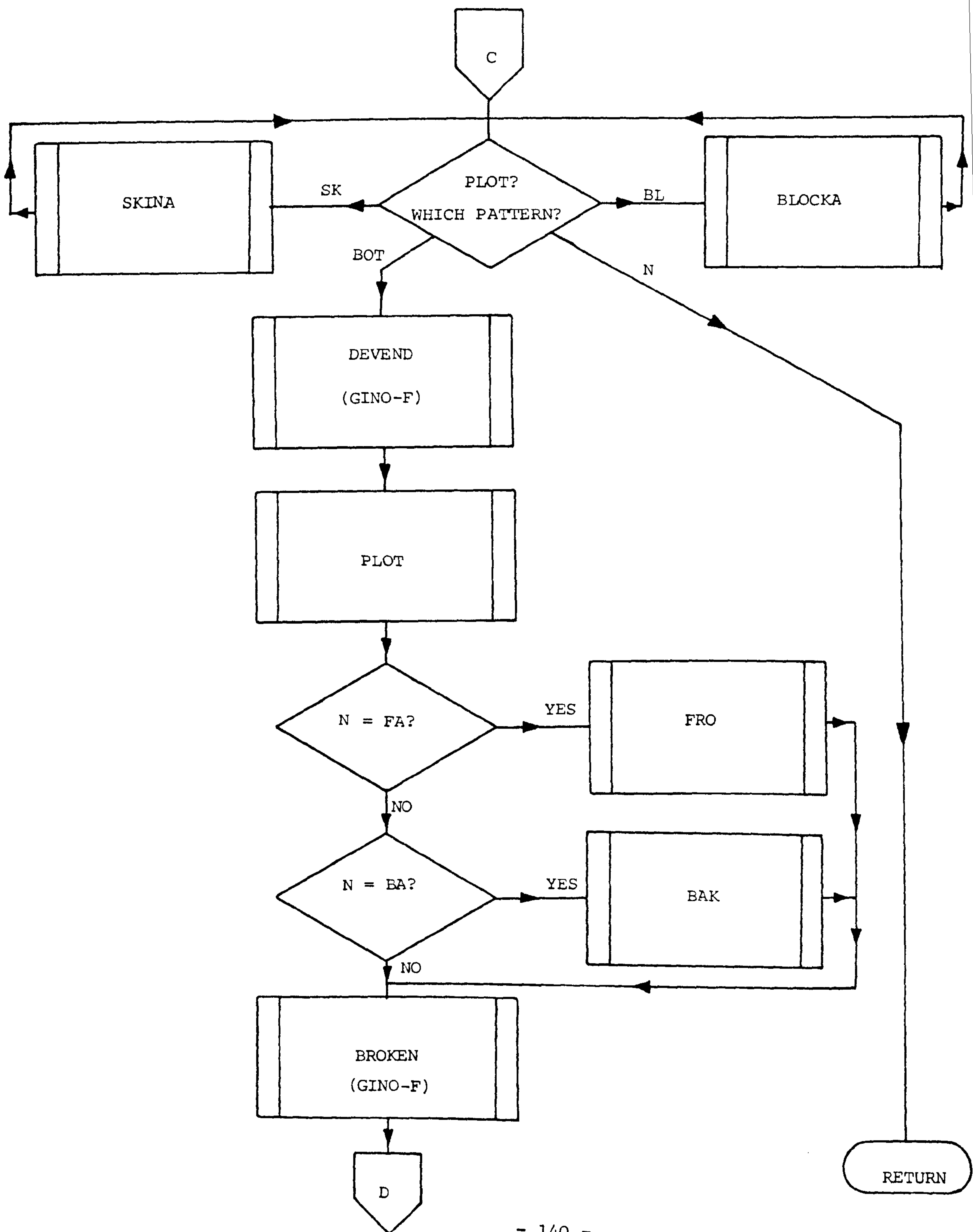
FLOW-CHART 2 : QUS ROUTINE

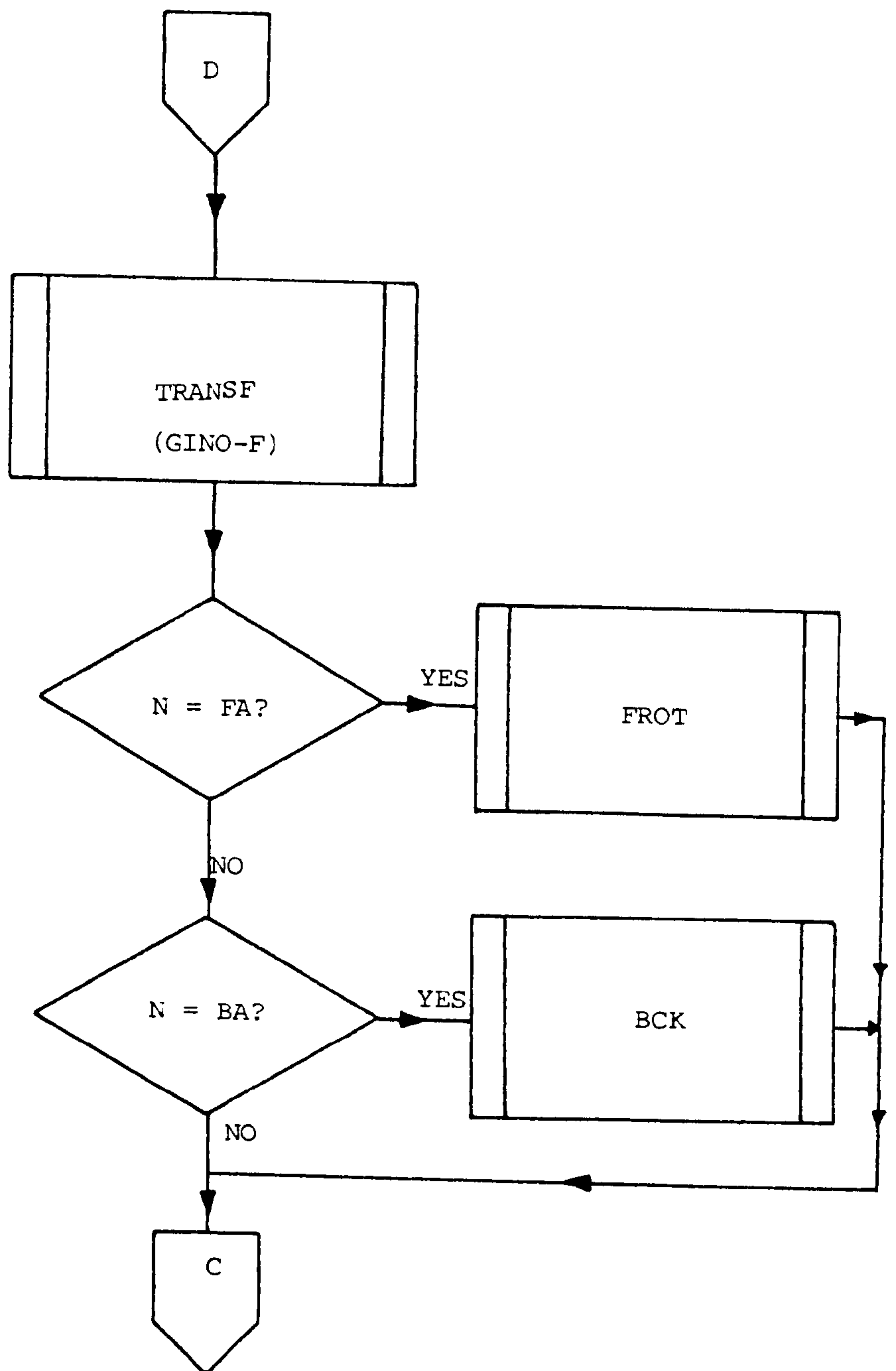


FLOW-CHART 3 : POL ROUTINE









10.3.3.4 Calculation Module

This section was designed to calculate all the necessary information and to provide the drawing and plotting module with the information needed to draw or plot the pattern either on the screen or by the plotter. The calculation module was divided into four routines as follows:

(i) The CALC Routine

This routine was divided into four sub-routines which together perform all the calculations needed for the drawing and plotting routines. It first reads all the pre-stored three-dimensional co-ordinates, reads all the factors needed for converting any curved lines into straight ones, multiplies each co-ordinate by its appropriate factor, and stores the results in an array for future use. Using the 'distance in space' formula (7.1), this routine then calculates the distances between the crucial shaping points and upon completion of the process, writes the result into a file.

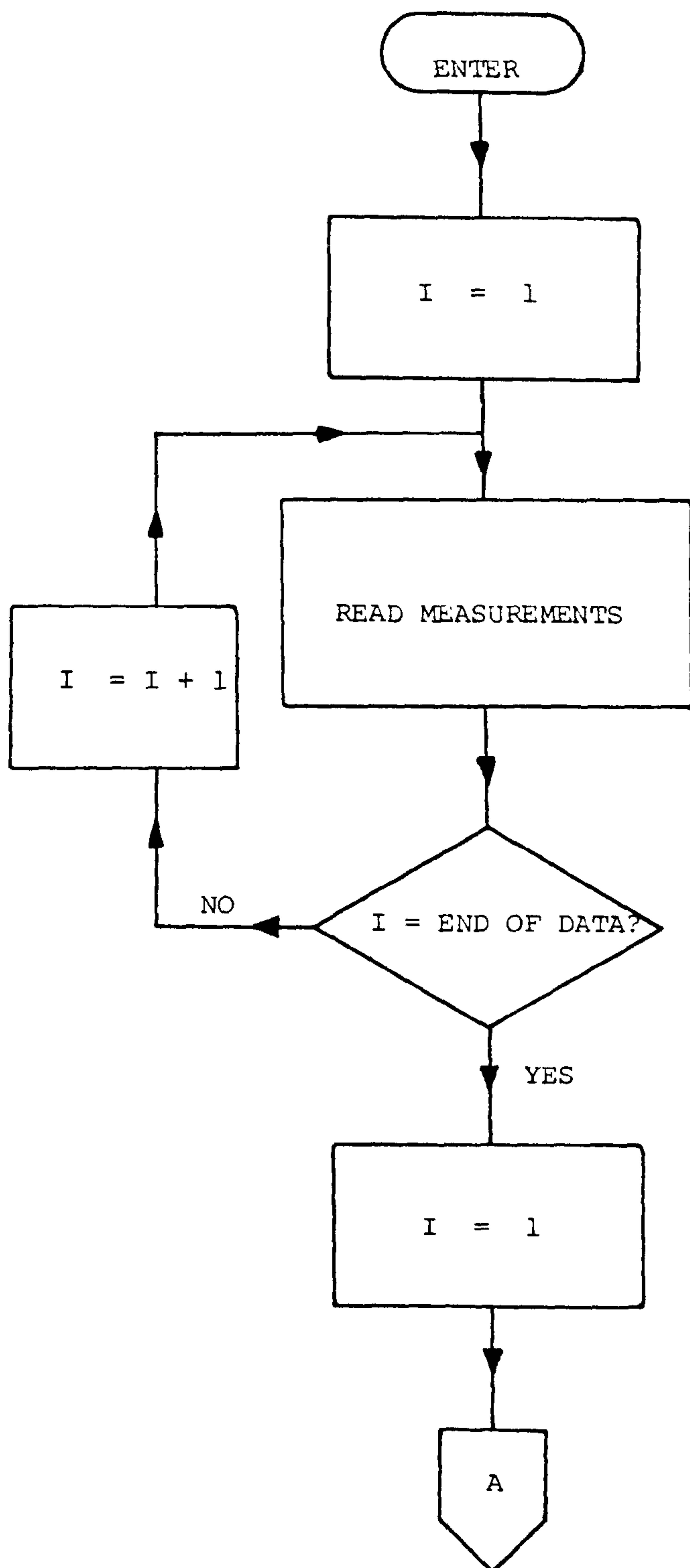
Having completed writing the results, the routine creates on each panel, a set of triangular sections radiating around the apex point. When this process has been completed, the routine makes a call to the ANGL sub-routine which was designed to make use of formula (7.2) and calculate the three angles in each of the triangles on each panel. It also writes all the results into an angle file for future use.

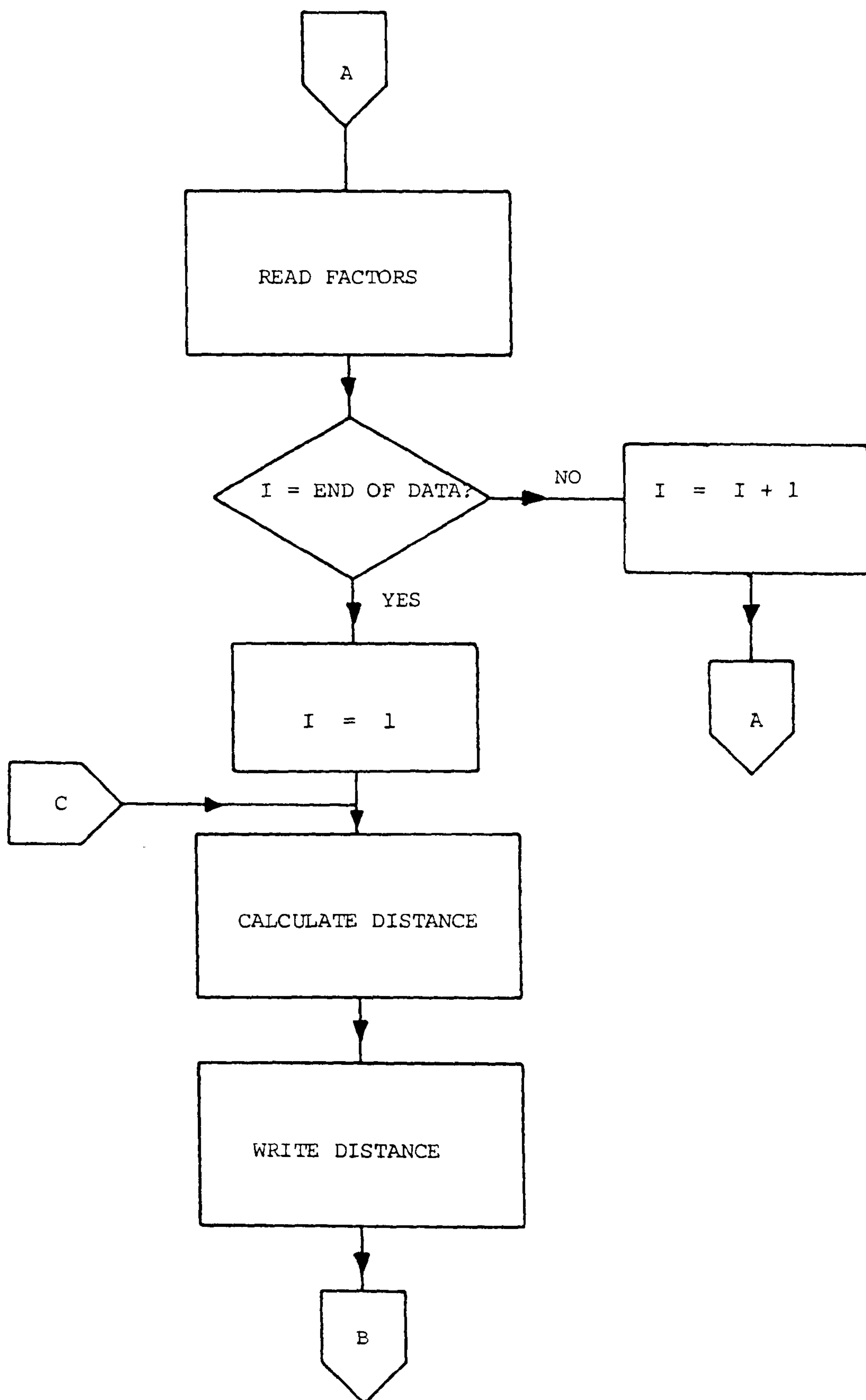
Upon completion of this process, a call is made to sub-routine TOTAL, which was designed to use formula (7.3) and to establish the missing angle of dart for each panel. Having obtained the missing angle of dart, the routine makes a call to the ZAV sub-routine, which distributes the angle of dart according to the exact size of dart needed for either upper or lower parts of each panel. To conclude the CALC routine, a call is made to the CORD sub-routine which by using formulae (9.4.1) and (9.4.2) calculates the two-dimensional co-ordinates needed for the two-dimensional pattern to be plotted and writes the results into a co-ordinate file which is stored for future use.

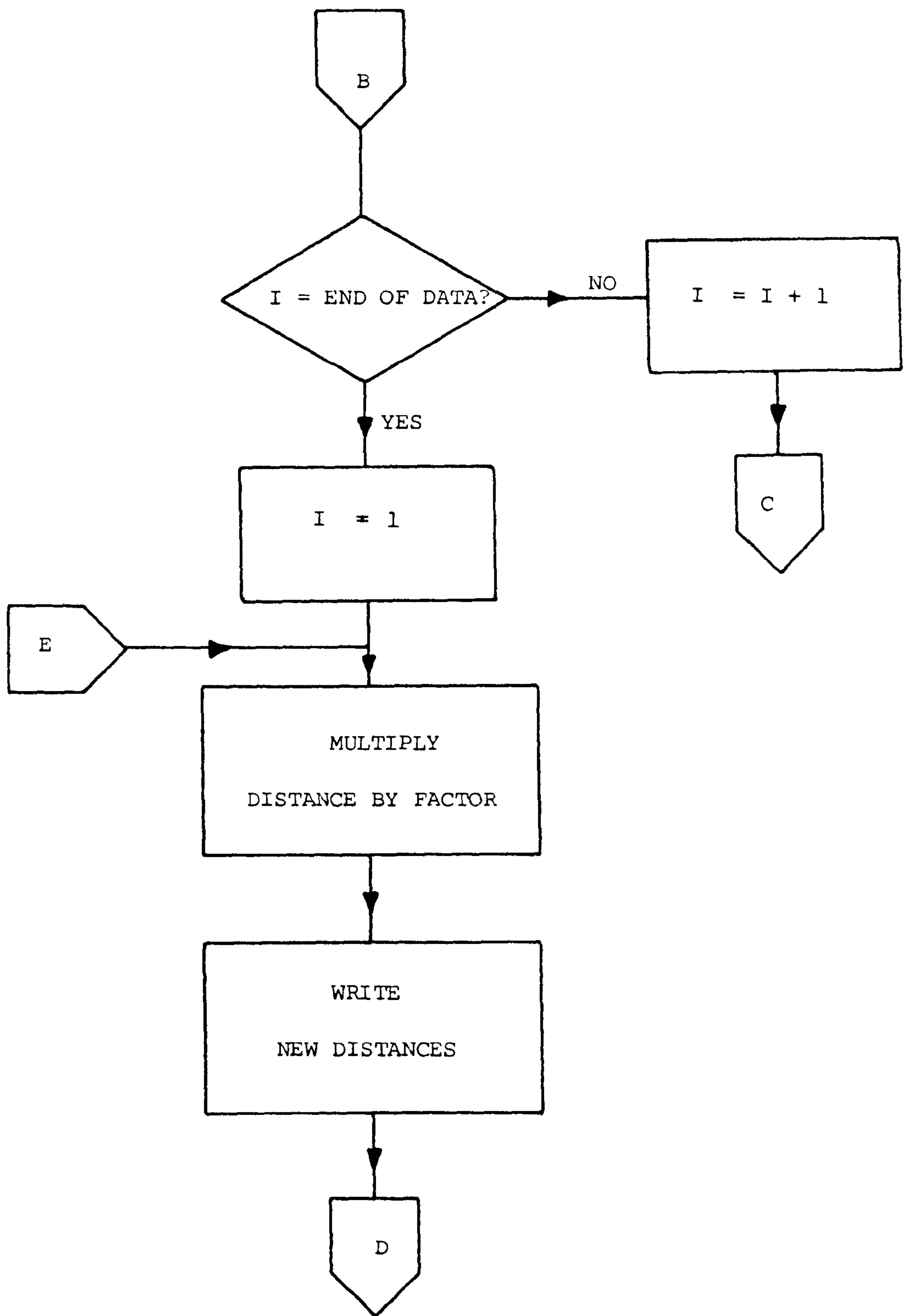
Upon completion of this routine, the software has created all the data needed for future calculation, drawing and plotting of any pattern available.

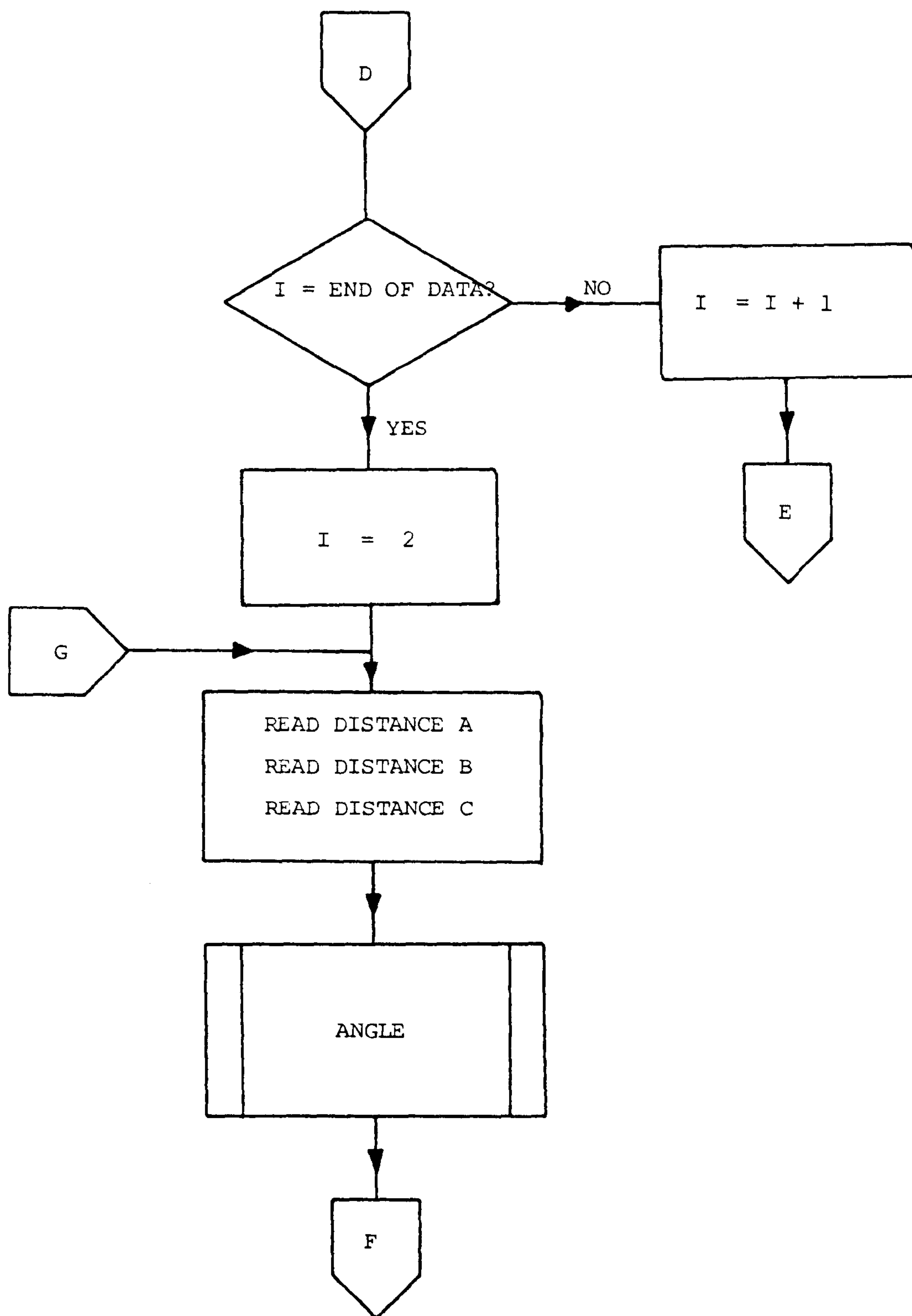
The structure of the CALC routine is illustrated in the following flow charts.

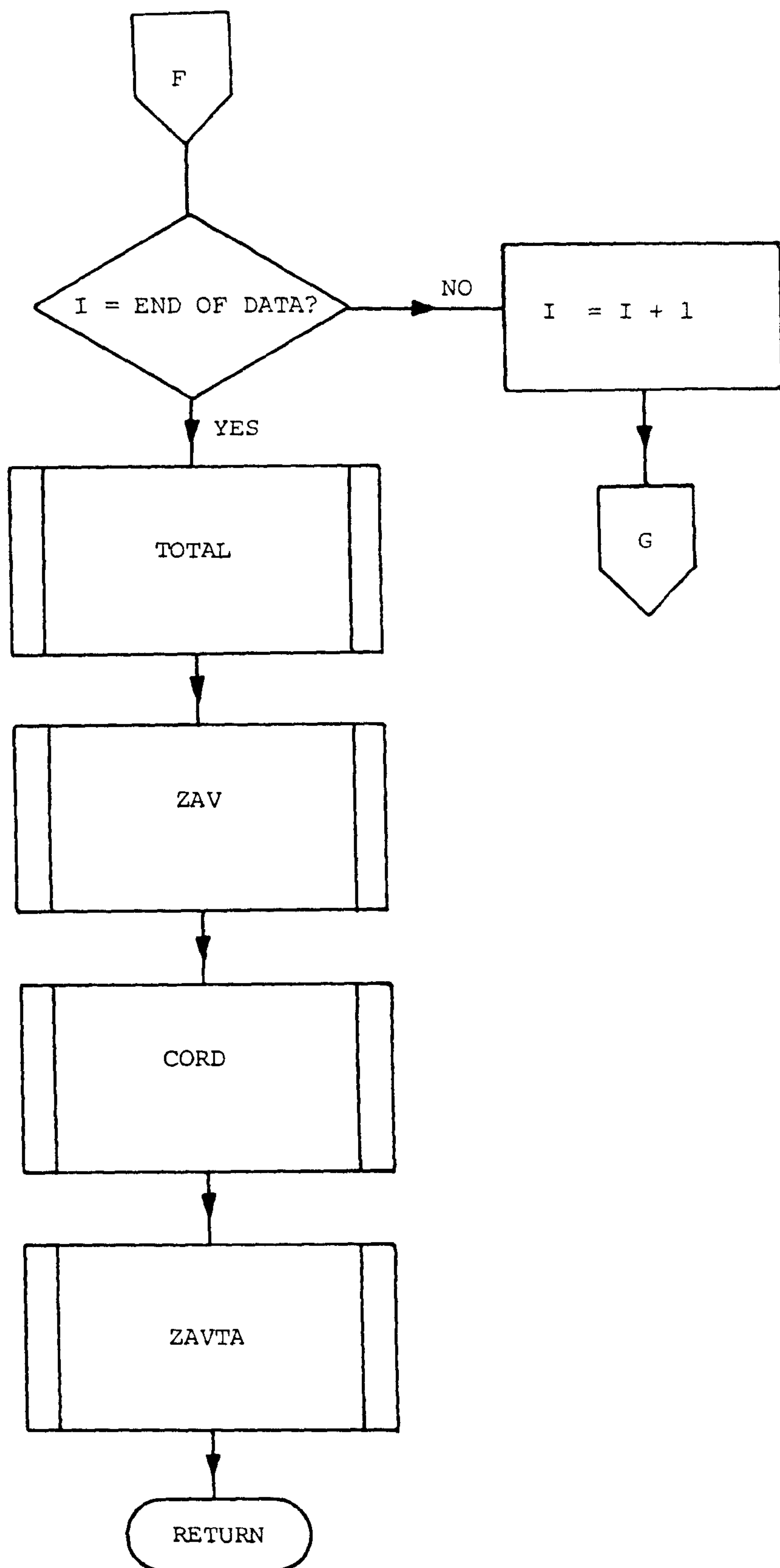
FLOW-CHART 4 : CALC ROUTINE



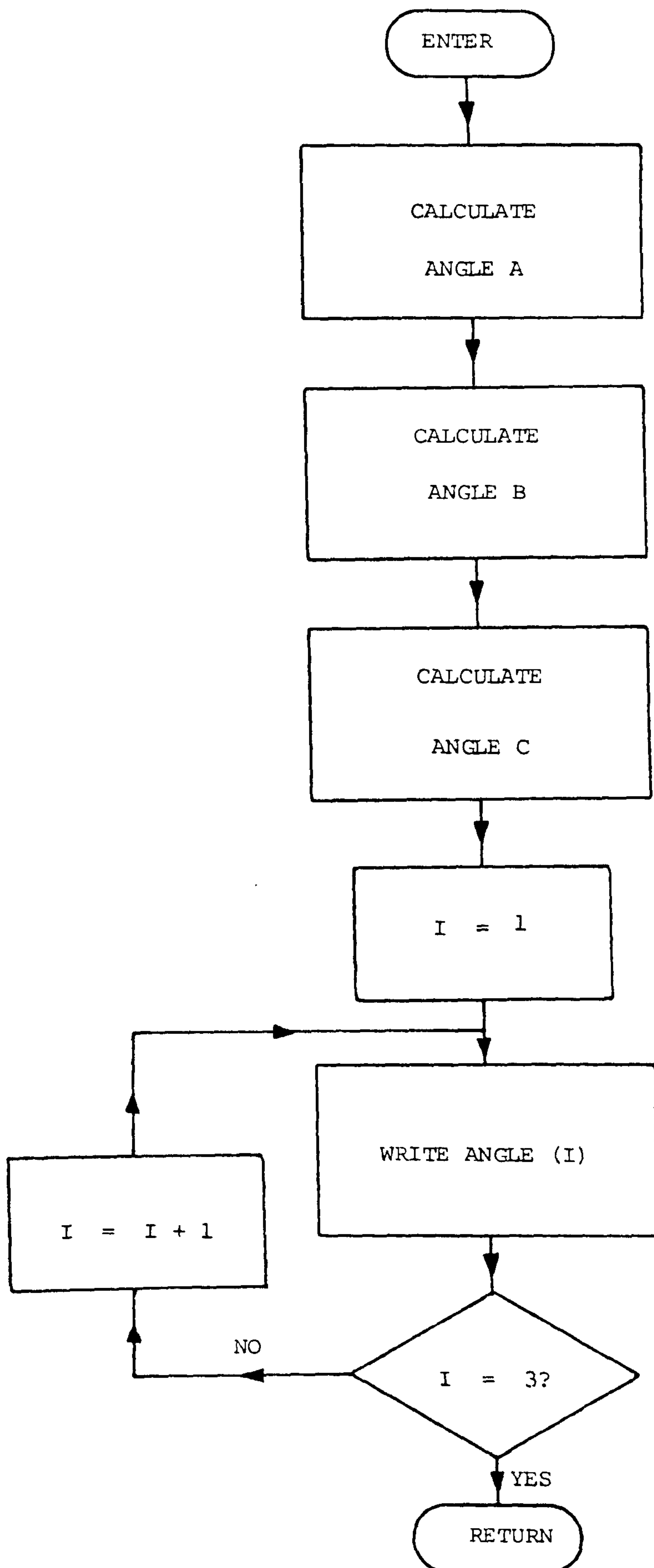




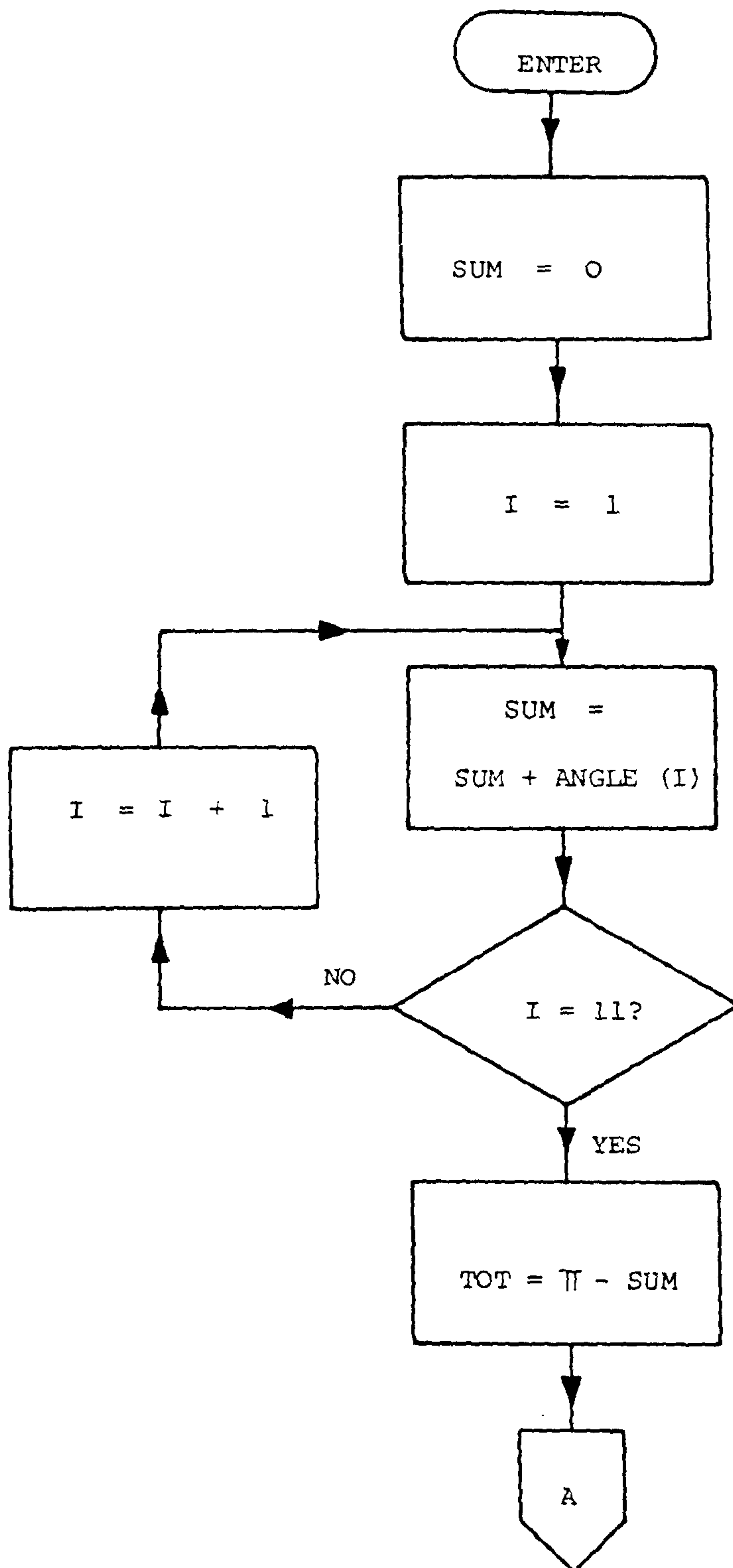


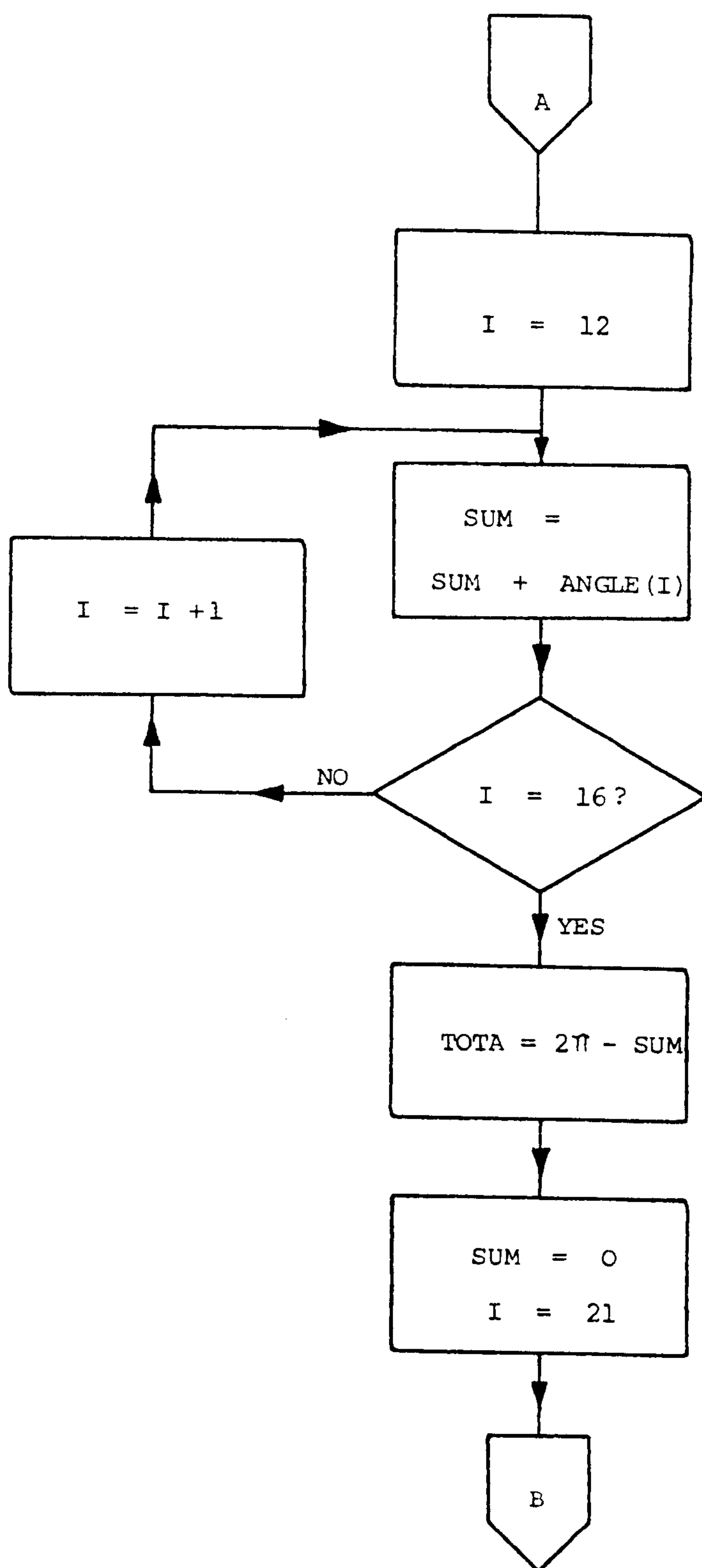


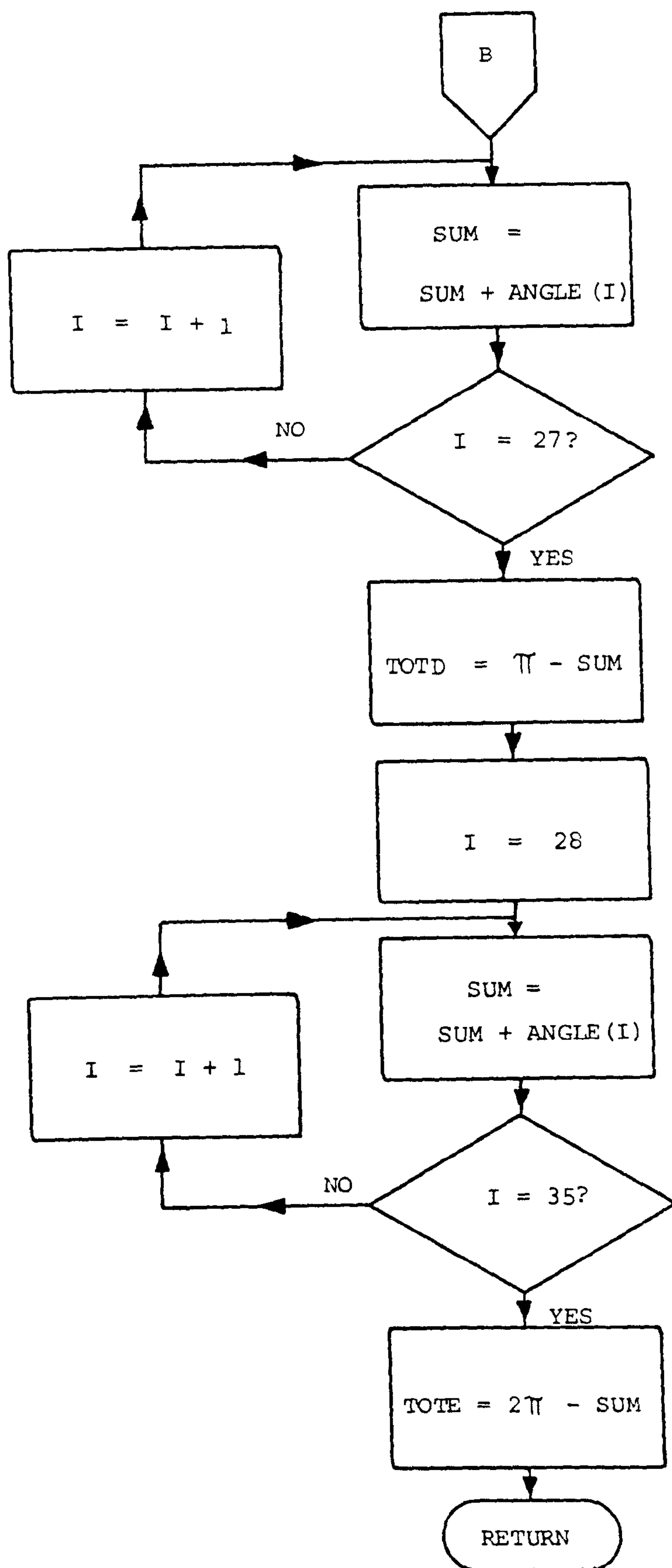
FLOW-CHART 5 : ANGL ROUTINE



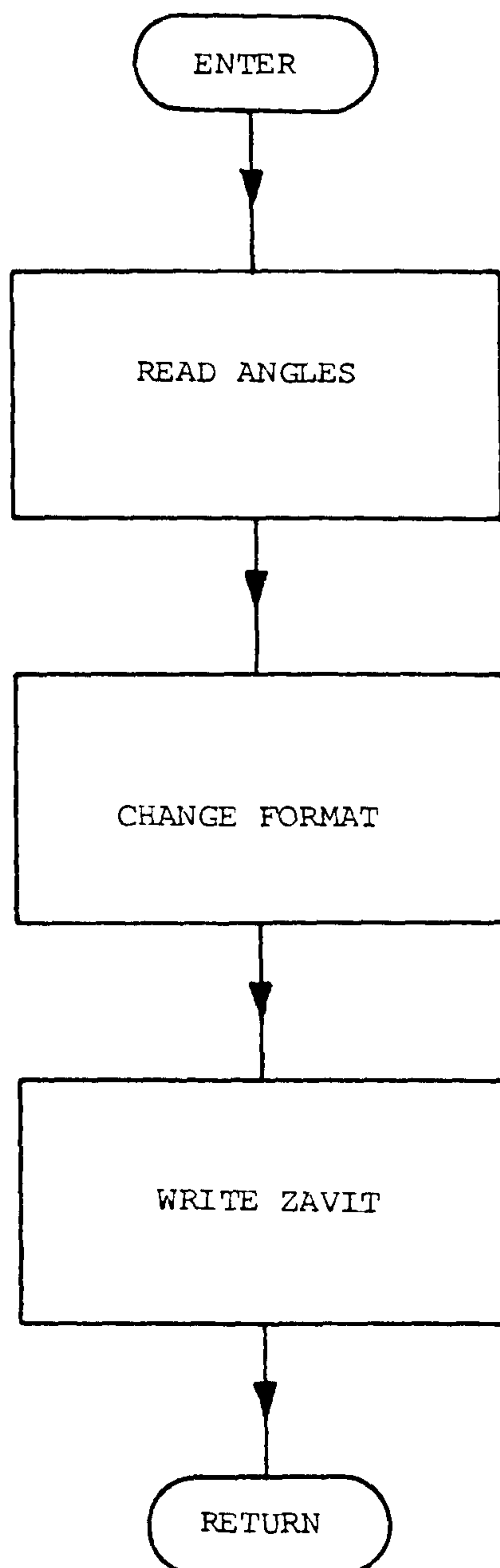
FLOW-CHART 6 : TOTAL SUB-ROUTINE



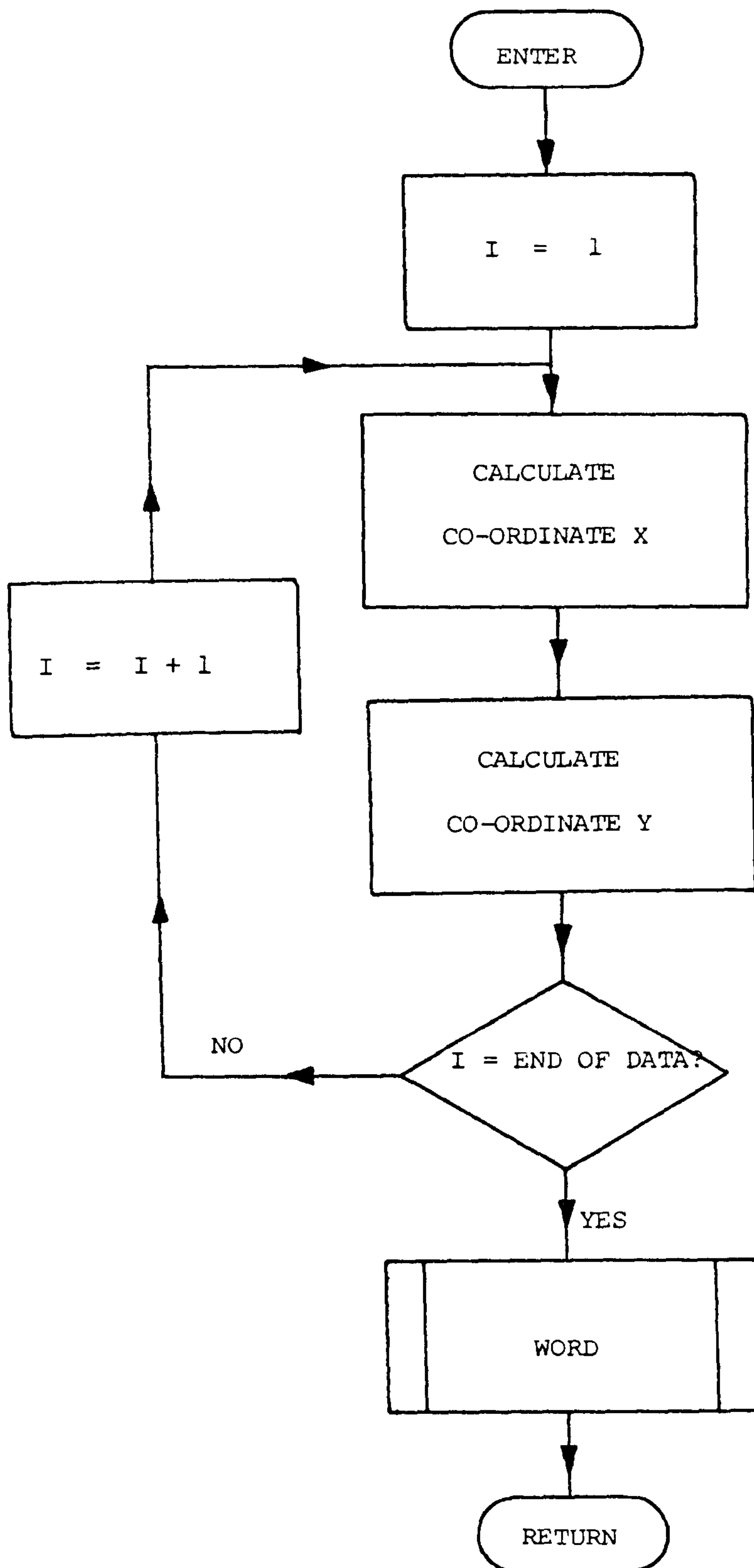




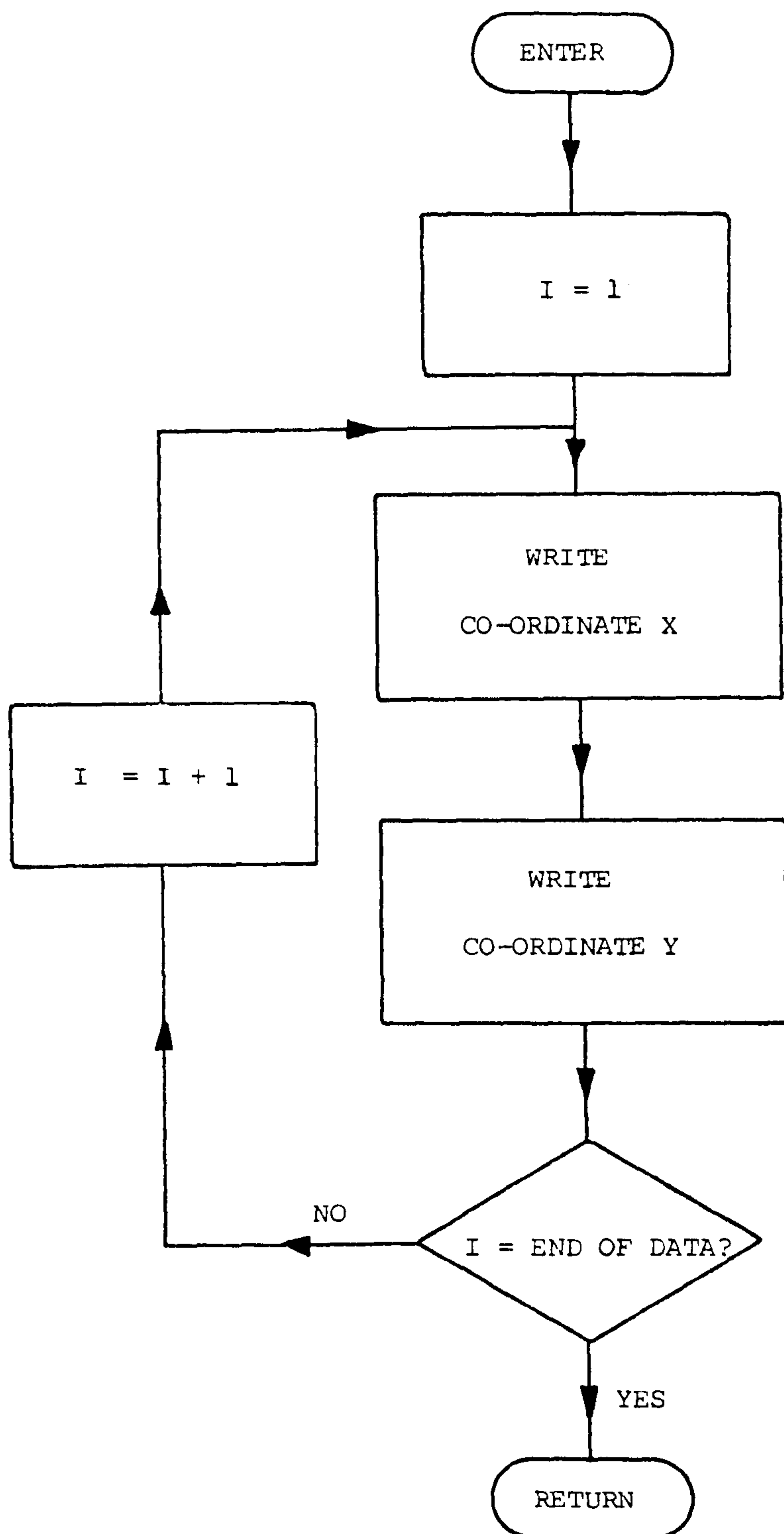
FLOW-CHART 7 : ZAV SUB-ROUTINE



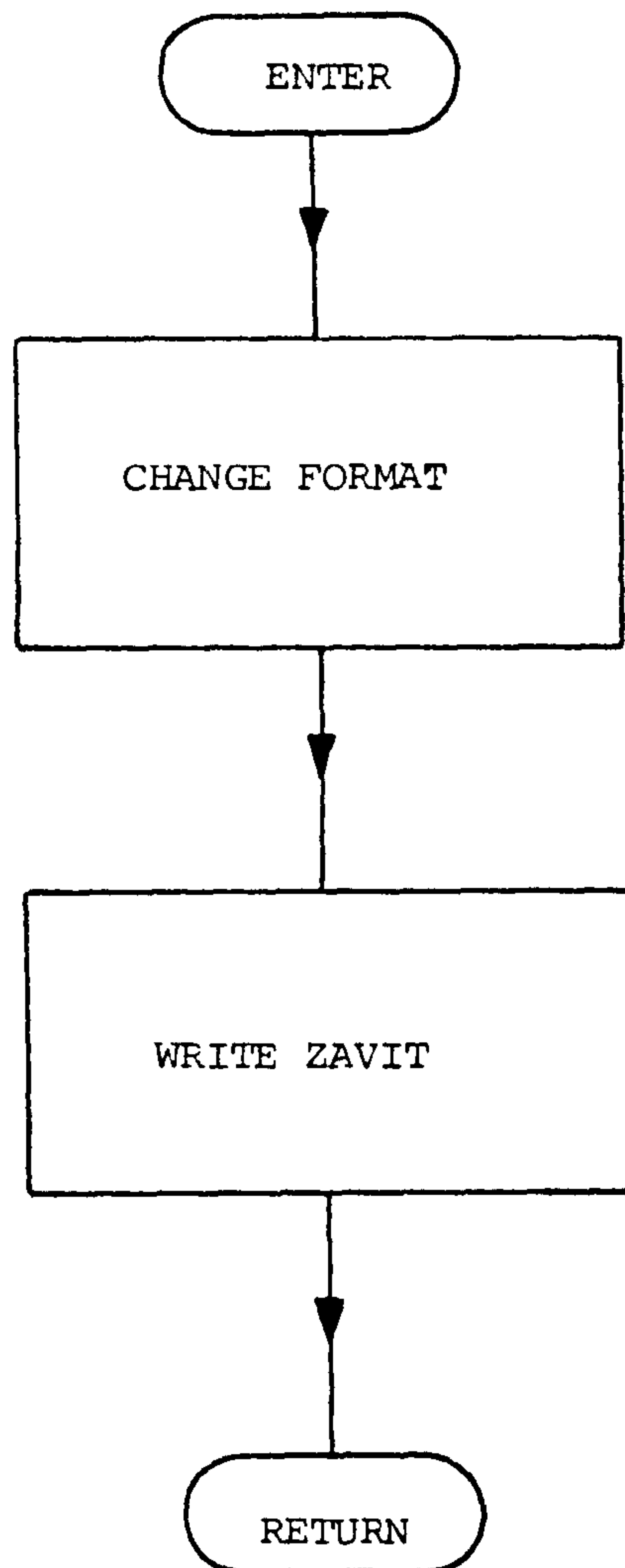
FLOW-CHART 8 : CORD SUB-ROUTINE



FLOW-CHART 9 : WORD SUB-ROUTINE



FLOW-CHART 10 : ZAVTA SUB-ROUTINE



(ii) The CON Routine

The purpose of this routine is to create and provide the co-ordinate file in the form suitable for use by the plotting routines. This routine reads the two-dimensional co-ordinates file, arranges the exact positioning of the darts and their tapering co-ordinates. Having completed this process, the routine then writes the arranged co-ordinates into a file and stores it for future use. (See flow chart 11).

(iii) The CANG Routine

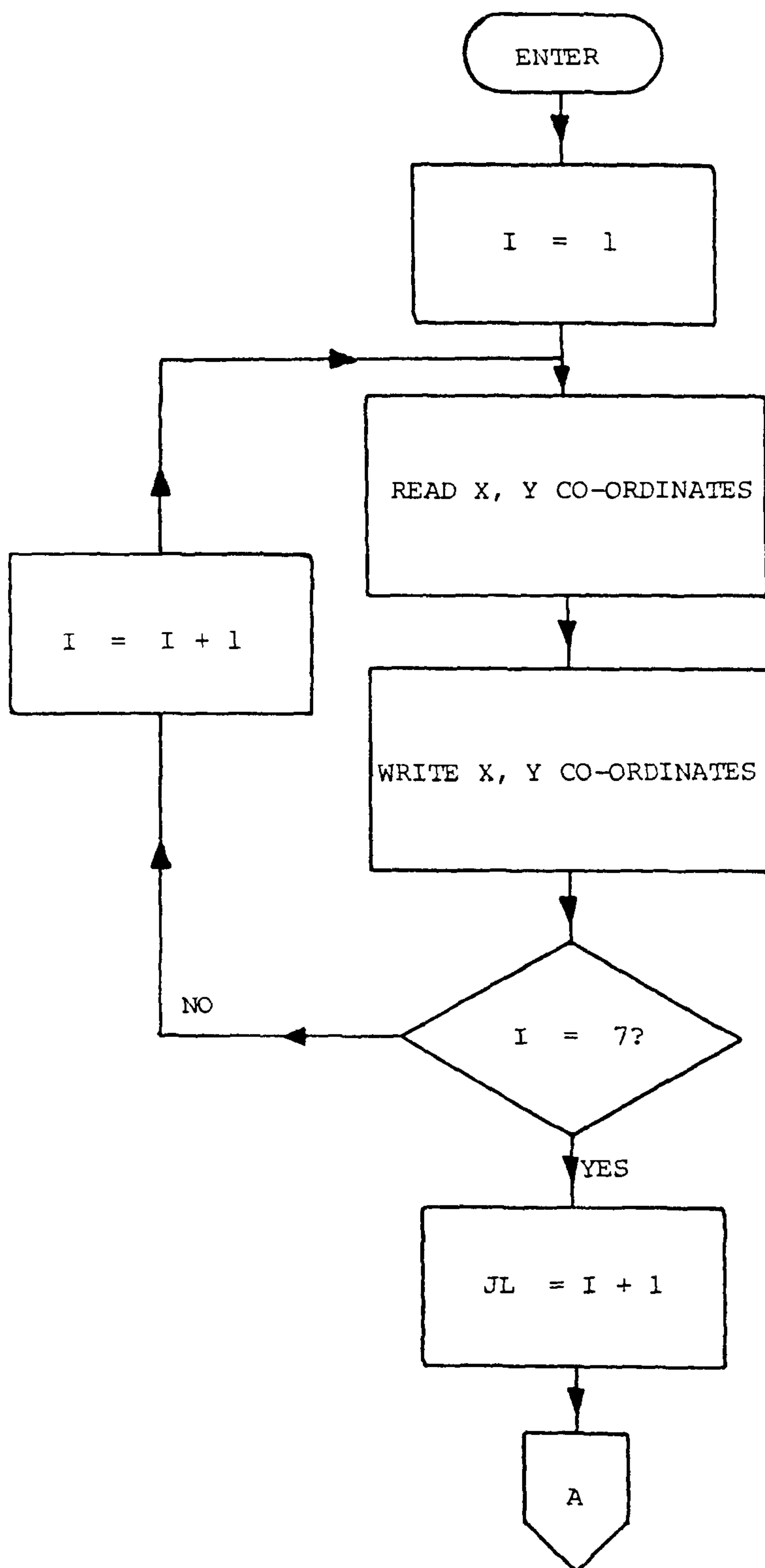
The purpose of this routine is to 'tidy up' the co-ordinates arranged by the CON routine. It ensures that the curved lines have been smoothly curved and the straight lines drawn and plotted straight. (See flow chart 13).

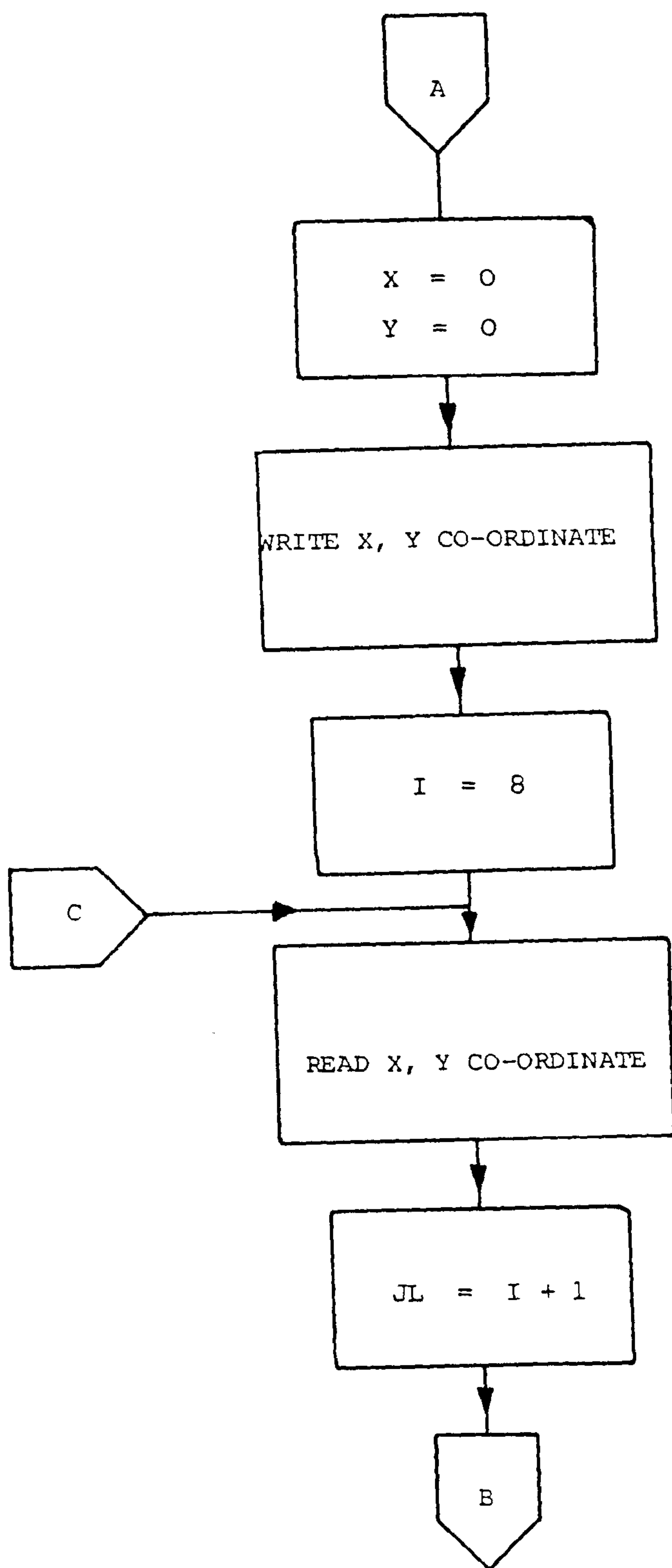
(iv) The EASE Routine

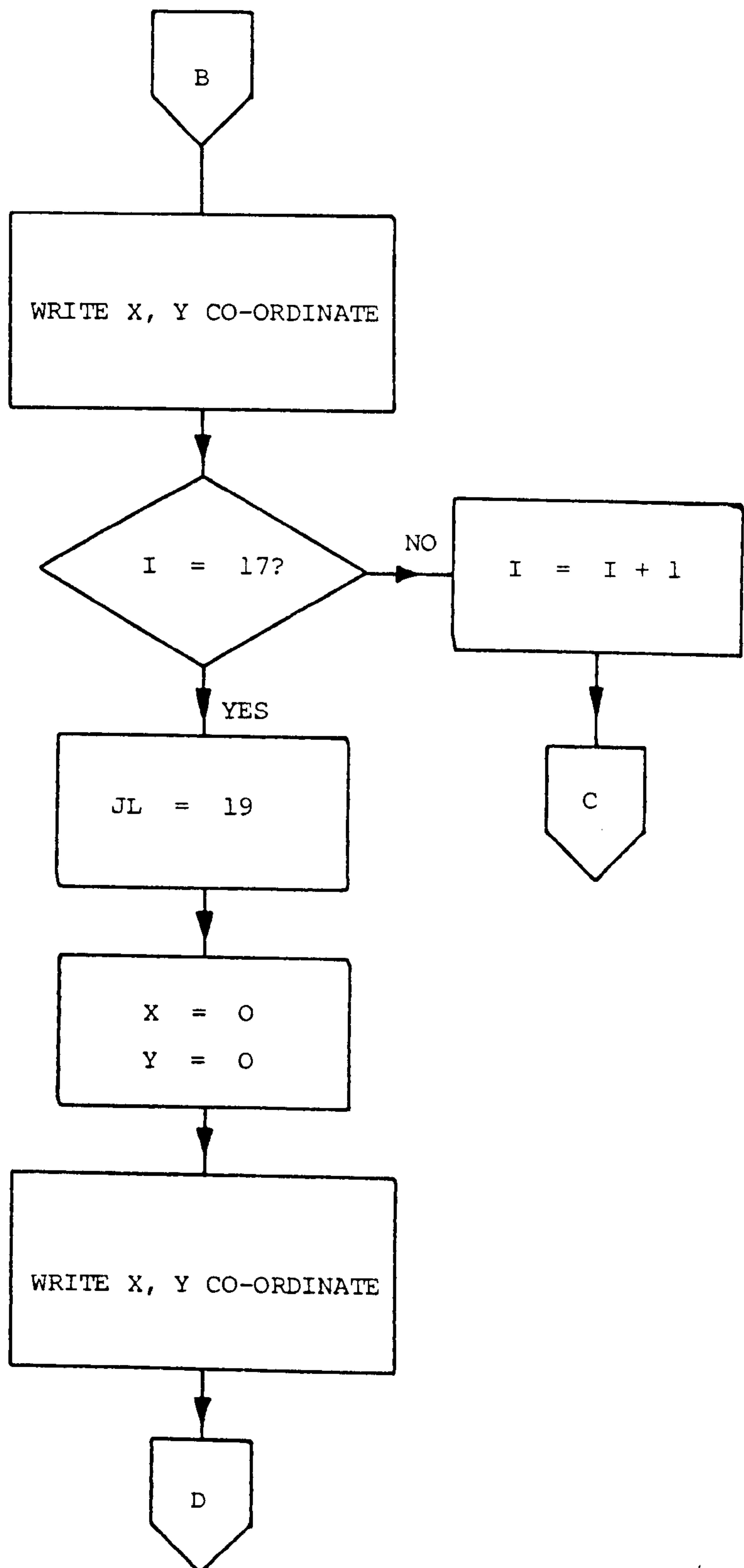
Before a block pattern can be produced, ease allowances must be added to the skin pattern. This function is carried out by the EASE routine, which provides the co-ordinates for plotting the block pattern. This routine reads the two-dimensional co-ordinates of the skin pattern, reads the ease allowances which have to be added to these co-ordinates, multiplies the co-ordinates of each point by the appropriate factor and writes the results into a block pattern co-ordinates file.

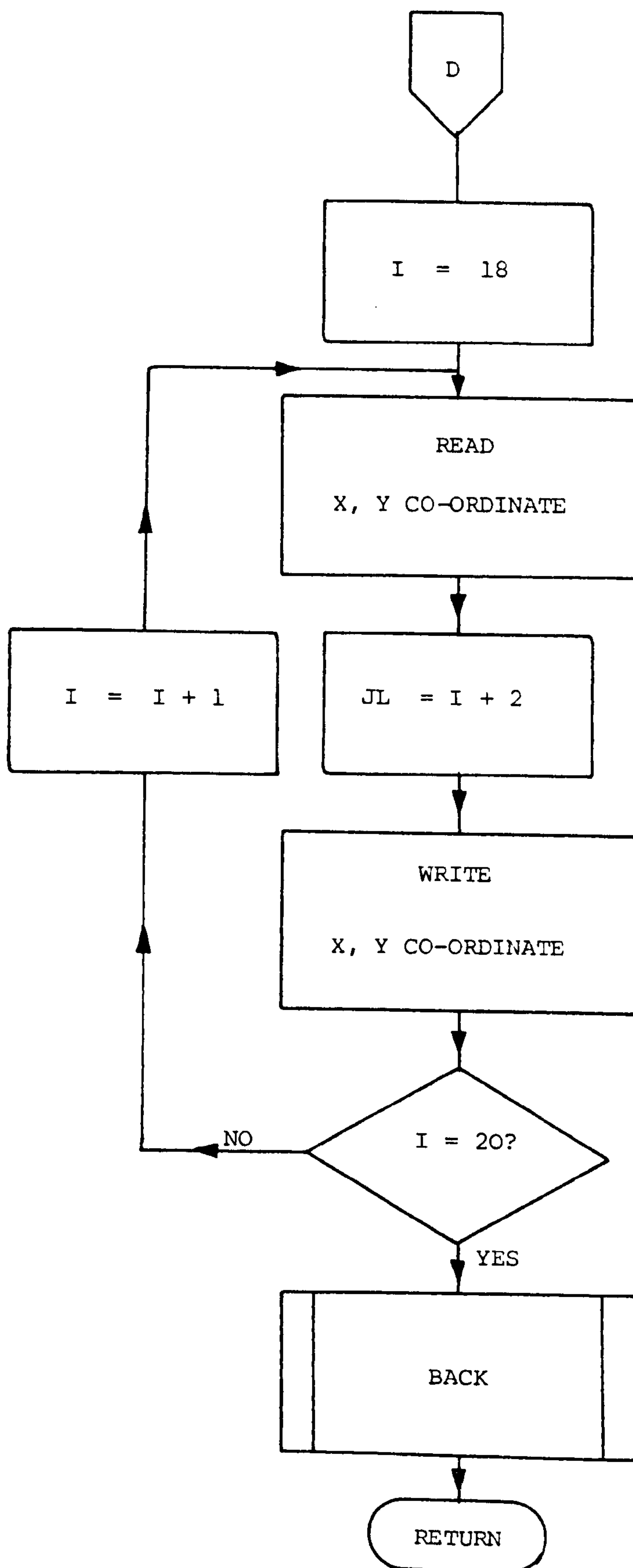
Upon completion of this process, the data is suitably presented for use by the plotting and drawing routines. (See flow chart 14).

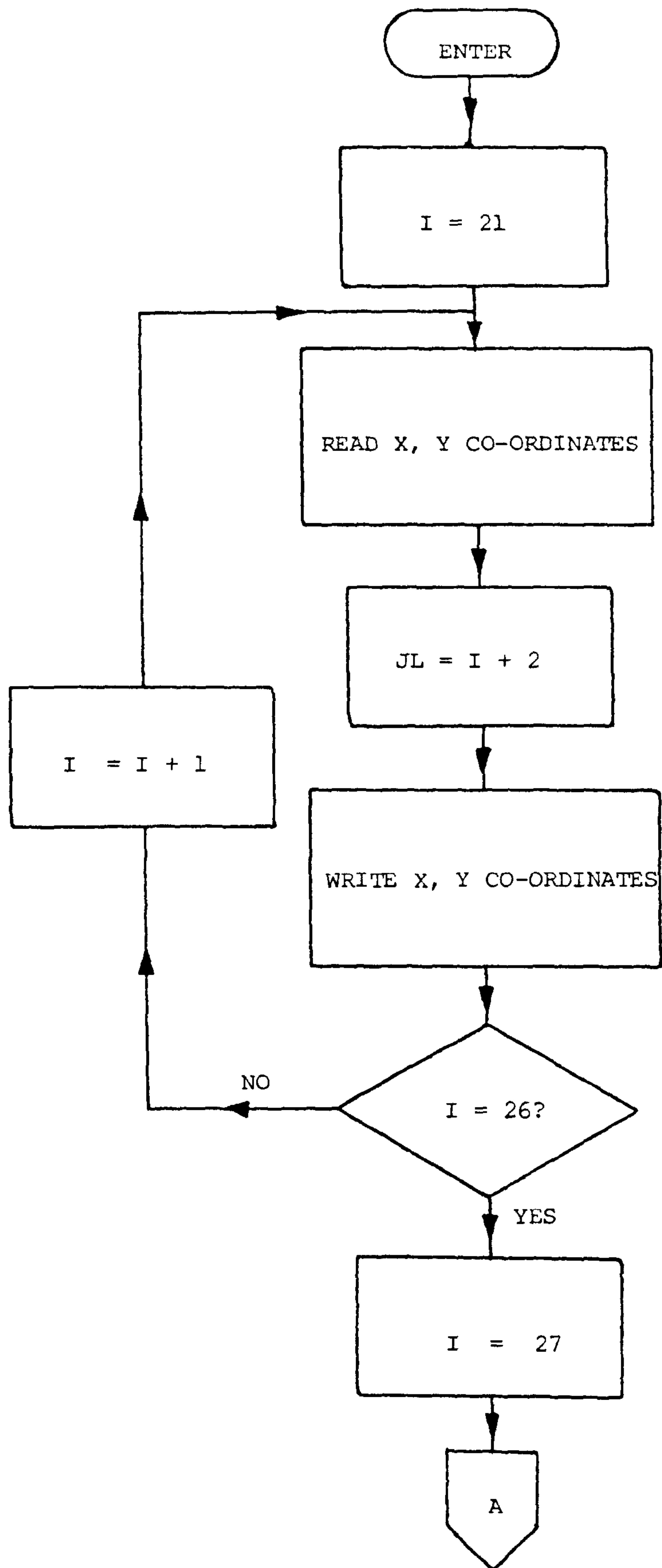
FLOW-CHART 11 : CON ROUTINE

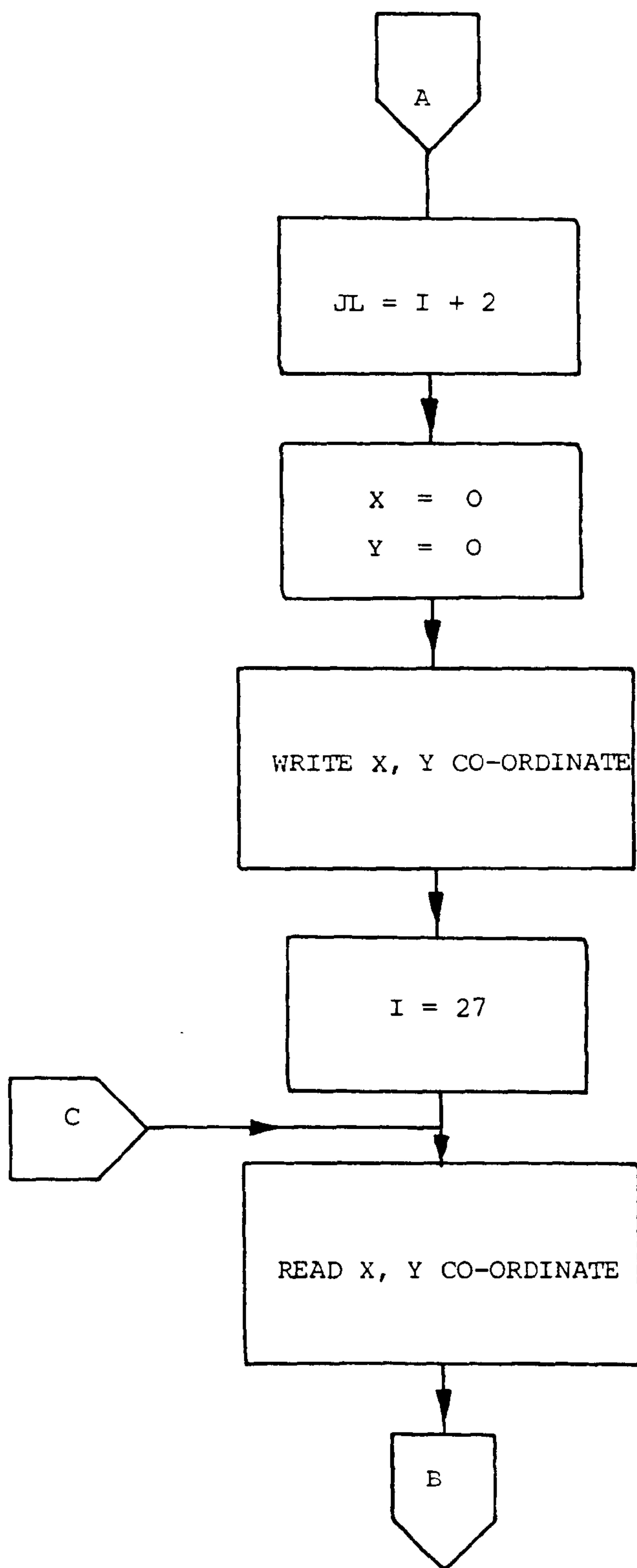


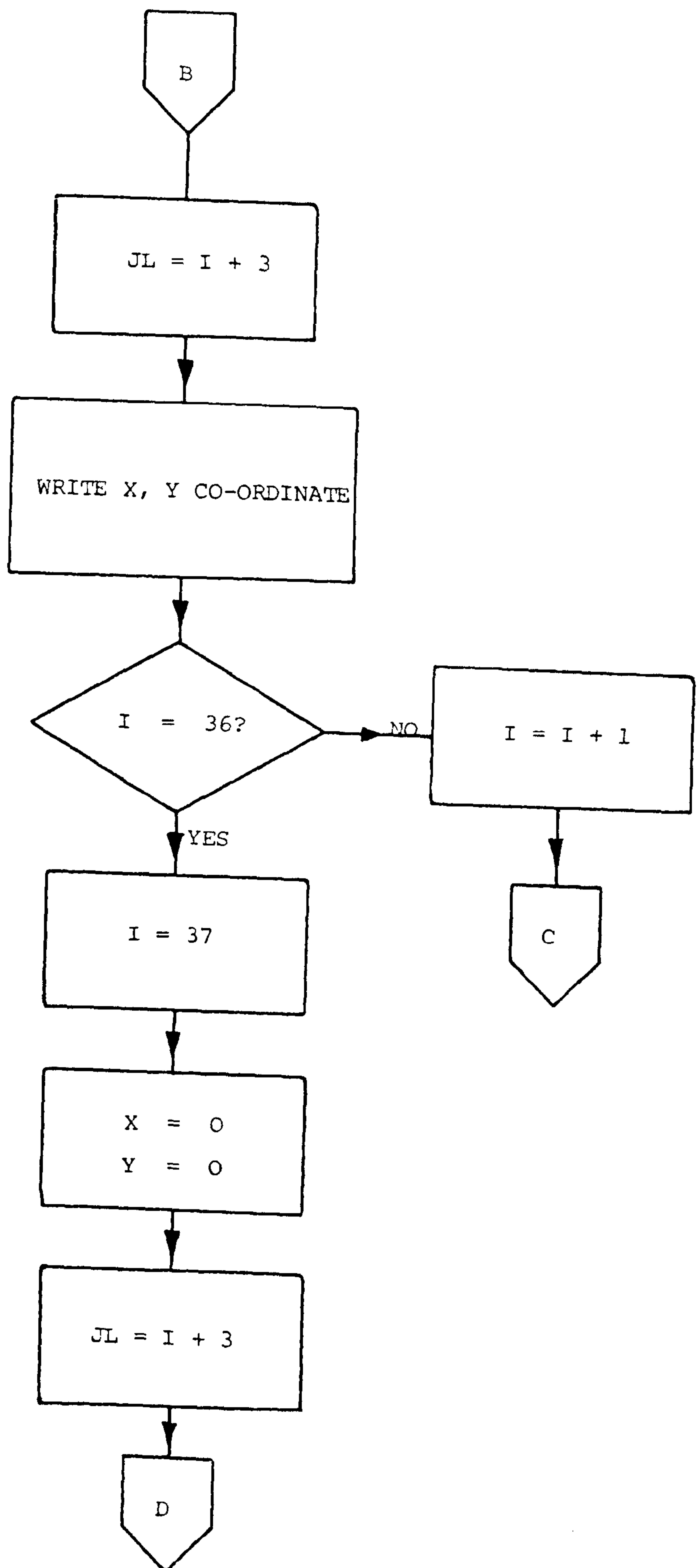


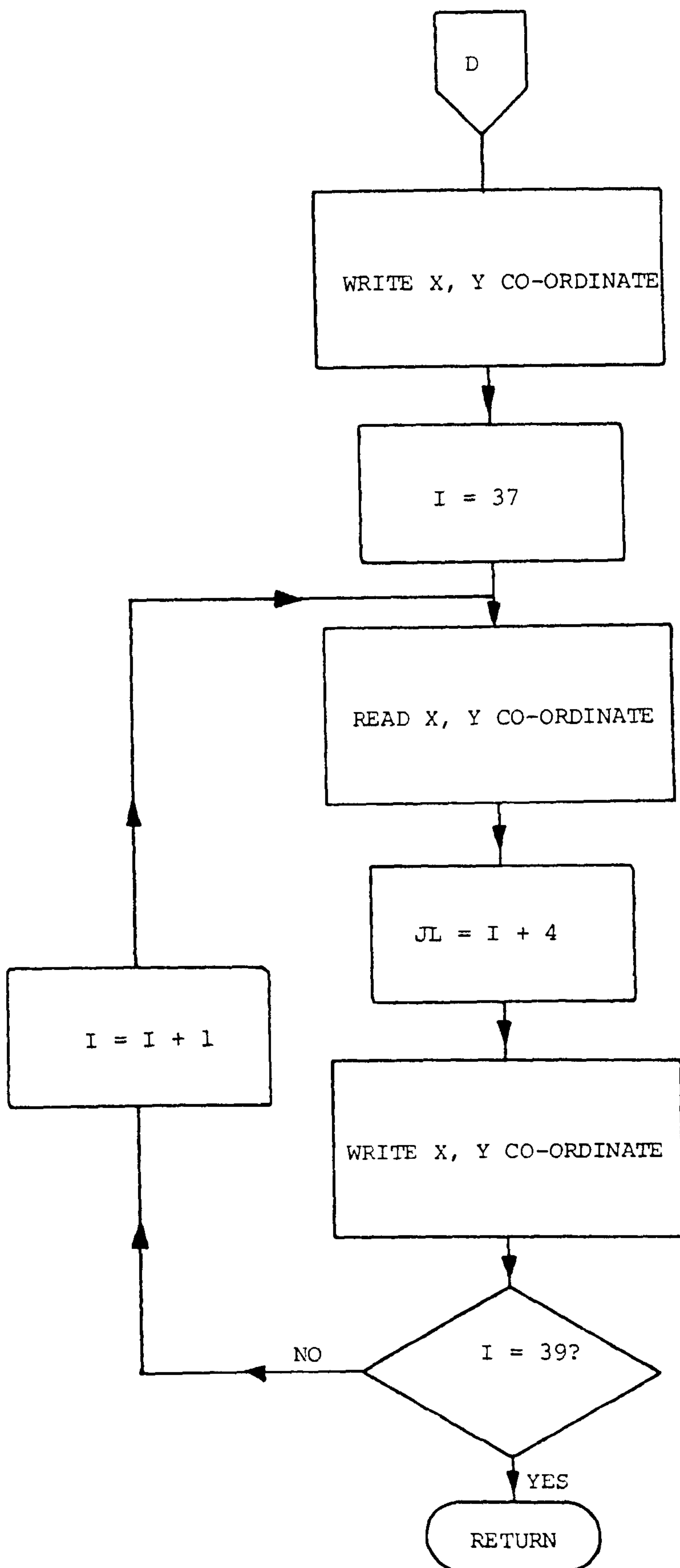




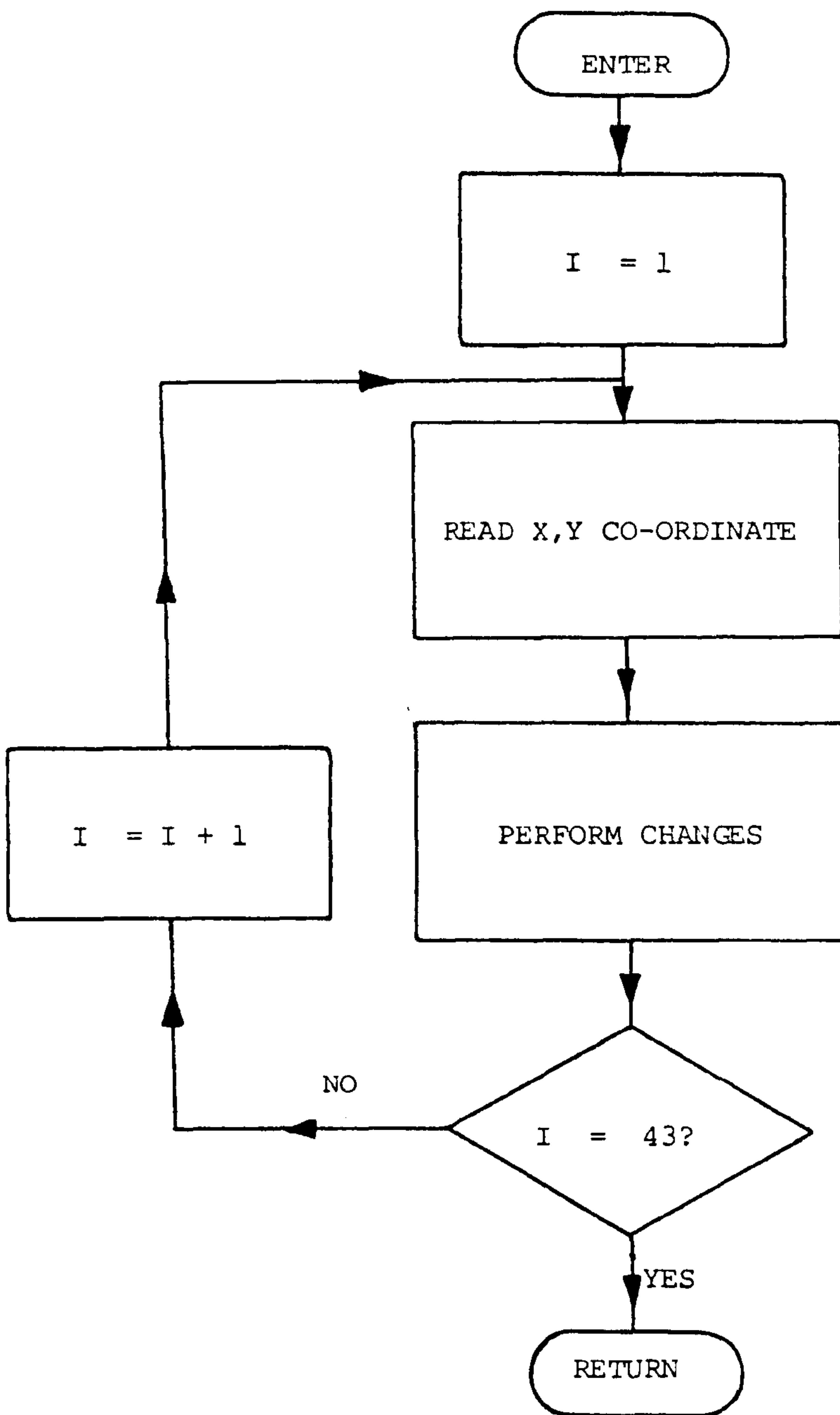




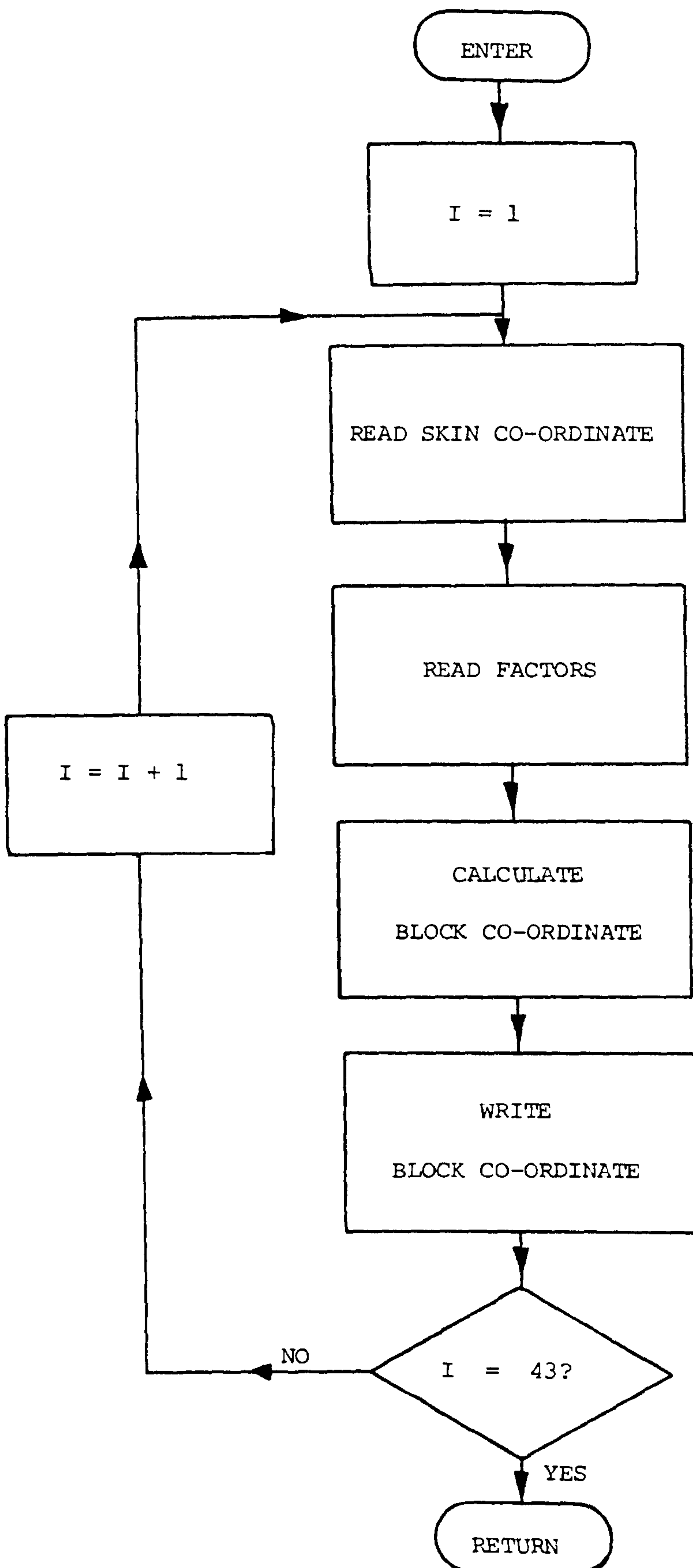




FLOW-CHART 13 : CHNG ROUTINE



FLOW-CHART 14 : EASE ROUTINE



10.3.3.5 Support Module

This section was designed to determine and control the areas where the patterns are to be either drawn on the screen or plotted by the plotter, and to create and establish the appropriate files needed for each drawing or plot. This section consists of six routines as follows:

(i) The SCREEN Routine

This routine consists of three sub-routines drawn from the GINO-F package, which selects the appropriate device, establishes the link between the computer and the selected device and scales down the co-ordinates to the appropriate size required by the device selected. (See flow chart 15).

(ii) The SHIF Routine

Before a pattern can be drawn on the screen, the initial origin of the drawing area must be established. The systems initial origin of the axes is in the bottom left hand corner of the drawing area. Since the pattern was designed to be drawn from its apex point, a different origin needs to be established. This routine establishes the new initial origin for each of the patterns to be plotted. (See flow chart 16).

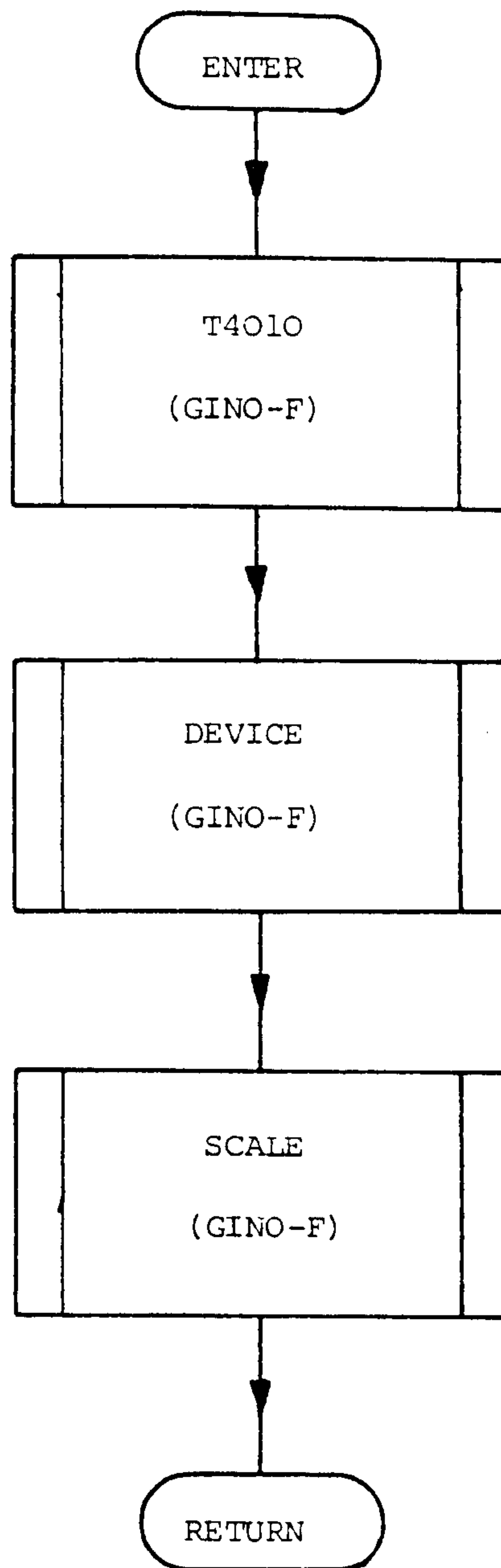
(iii) The Plot Routines

In addition to the new origin, the area of the plot, the units by which the pattern is to be plotted, the scale of the pattern and the plot file for each pattern available, need to be established.

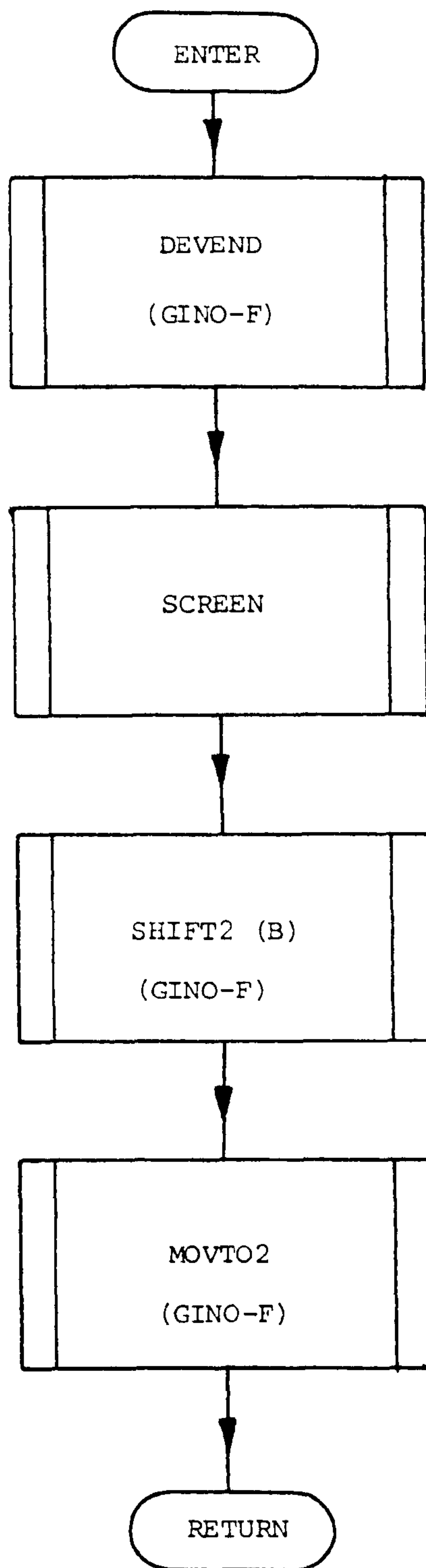
The plot routines which include the 'SKIN', 'SKINA', 'BLOCK', 'BLOCKA' and 'PLOT' routines, consist of a number of GINO-F sub-routines which establish the area, selects the units and creates a plot file for each of the patterns to be plotted.

The structure of each of these routines is shown in the following flow charts.

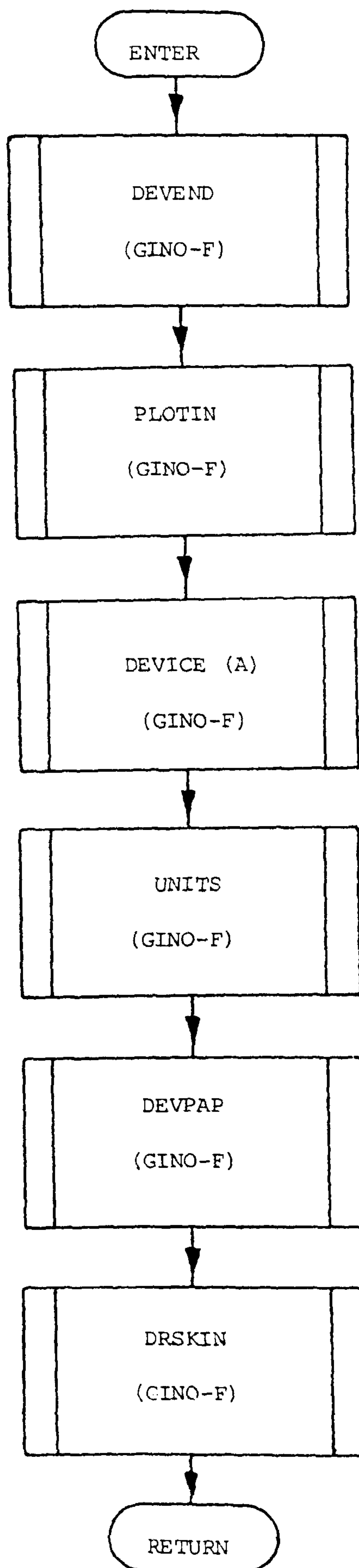
FLOW-CHART 15 : SCREEN ROUTINE



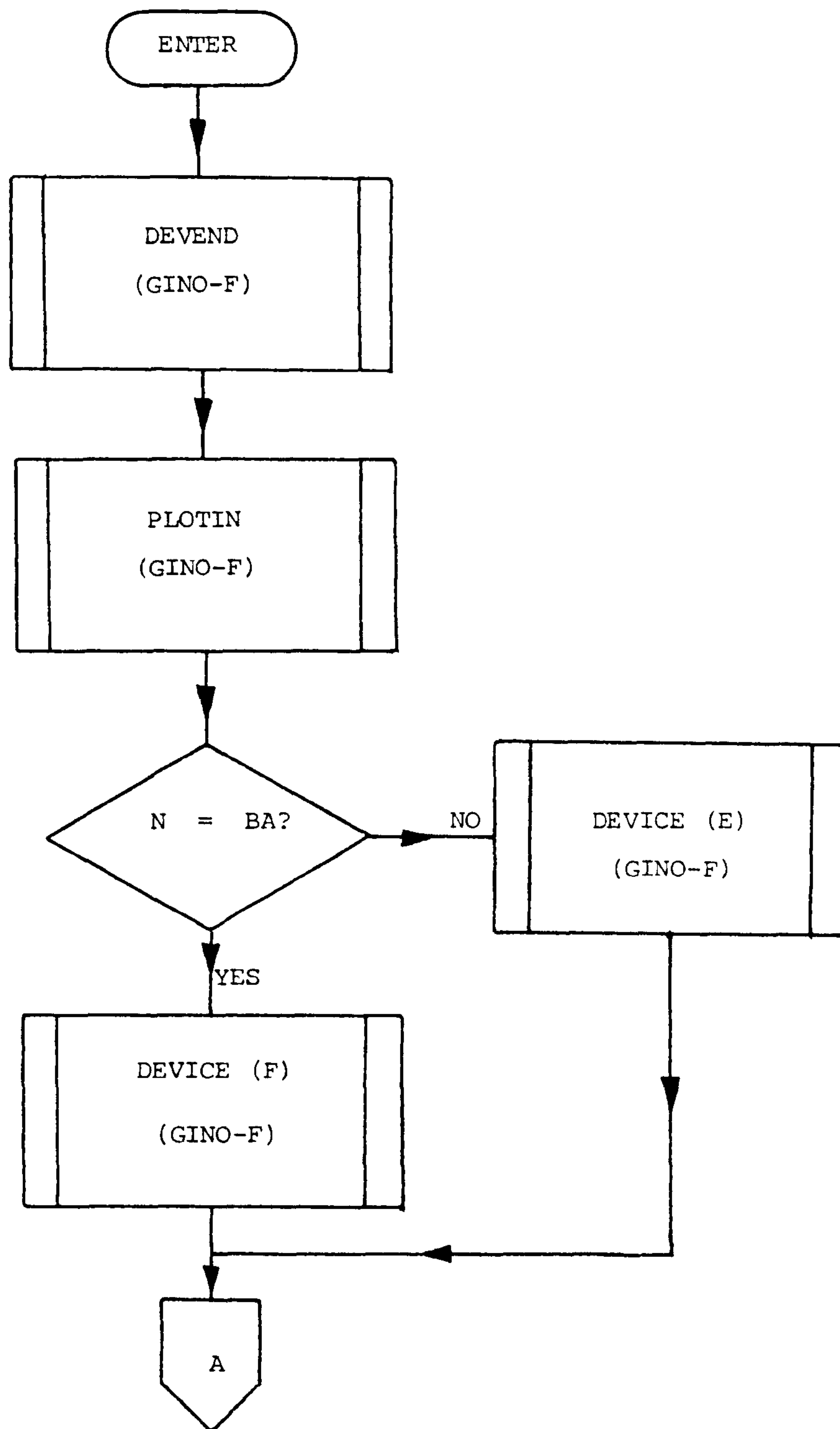
FLOW-CHART 16 : SHIF ROUTINE

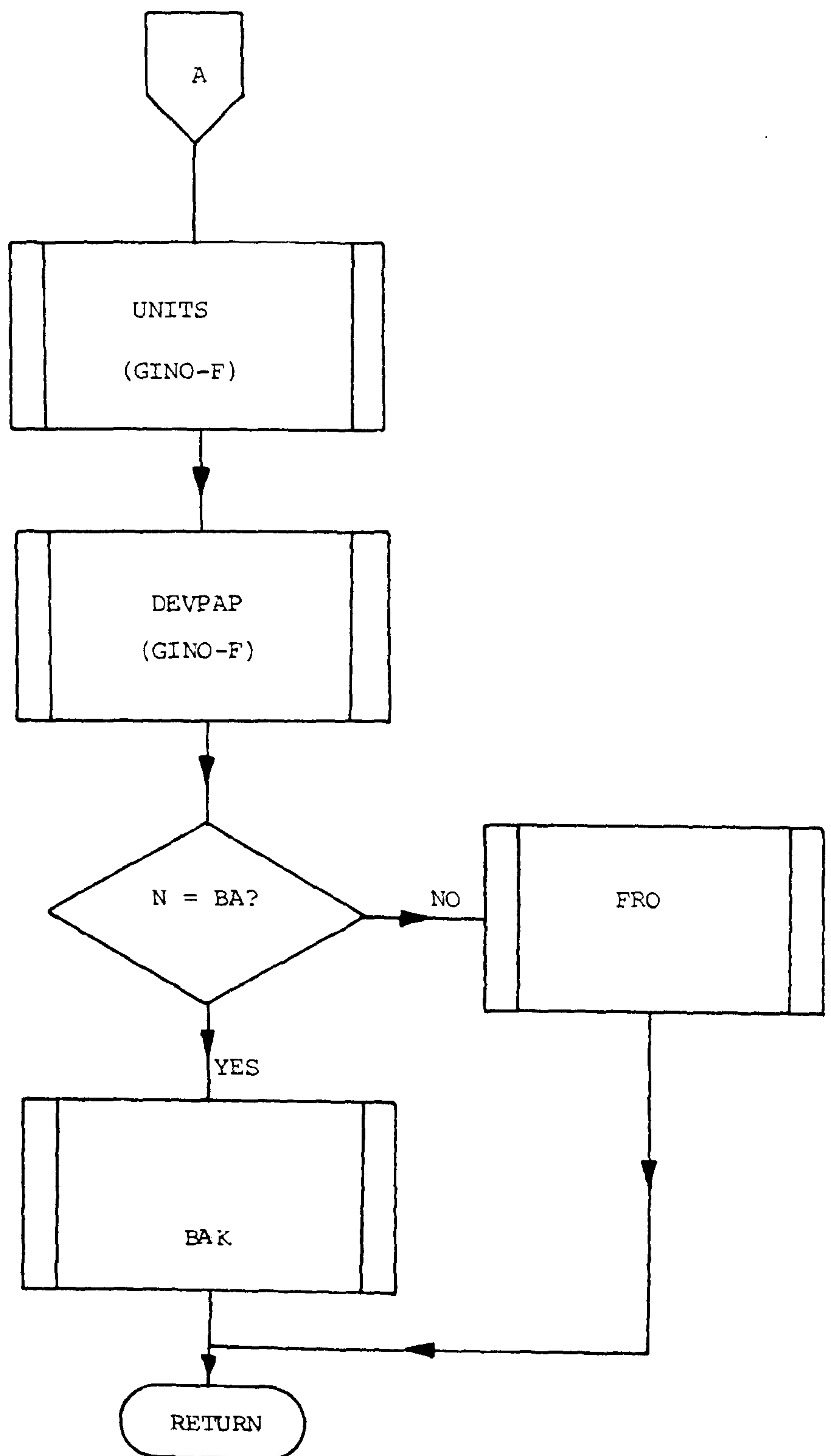


FLOW-CHART 17 : SKIN ROUTINE

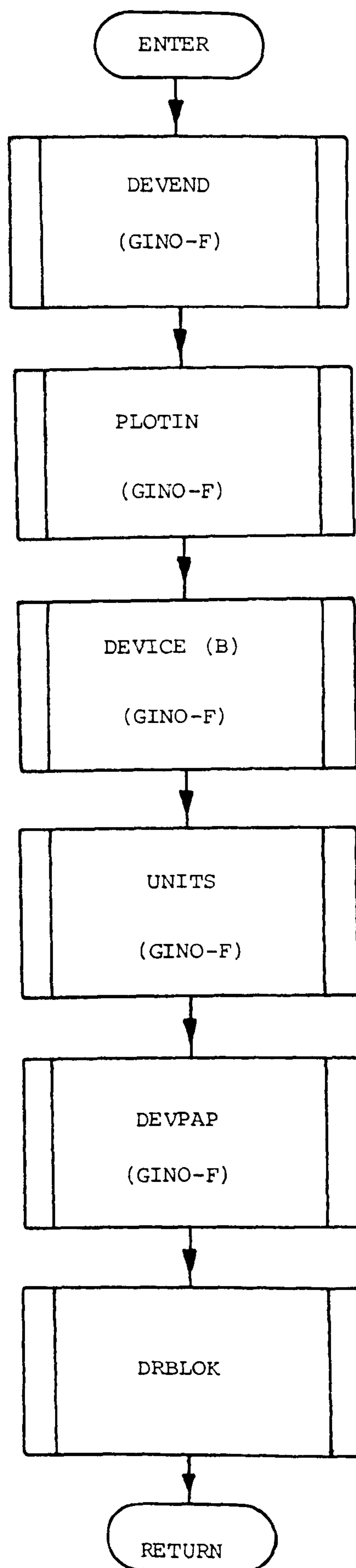


FLOW-CHART 18 : SKINA ROUTINE

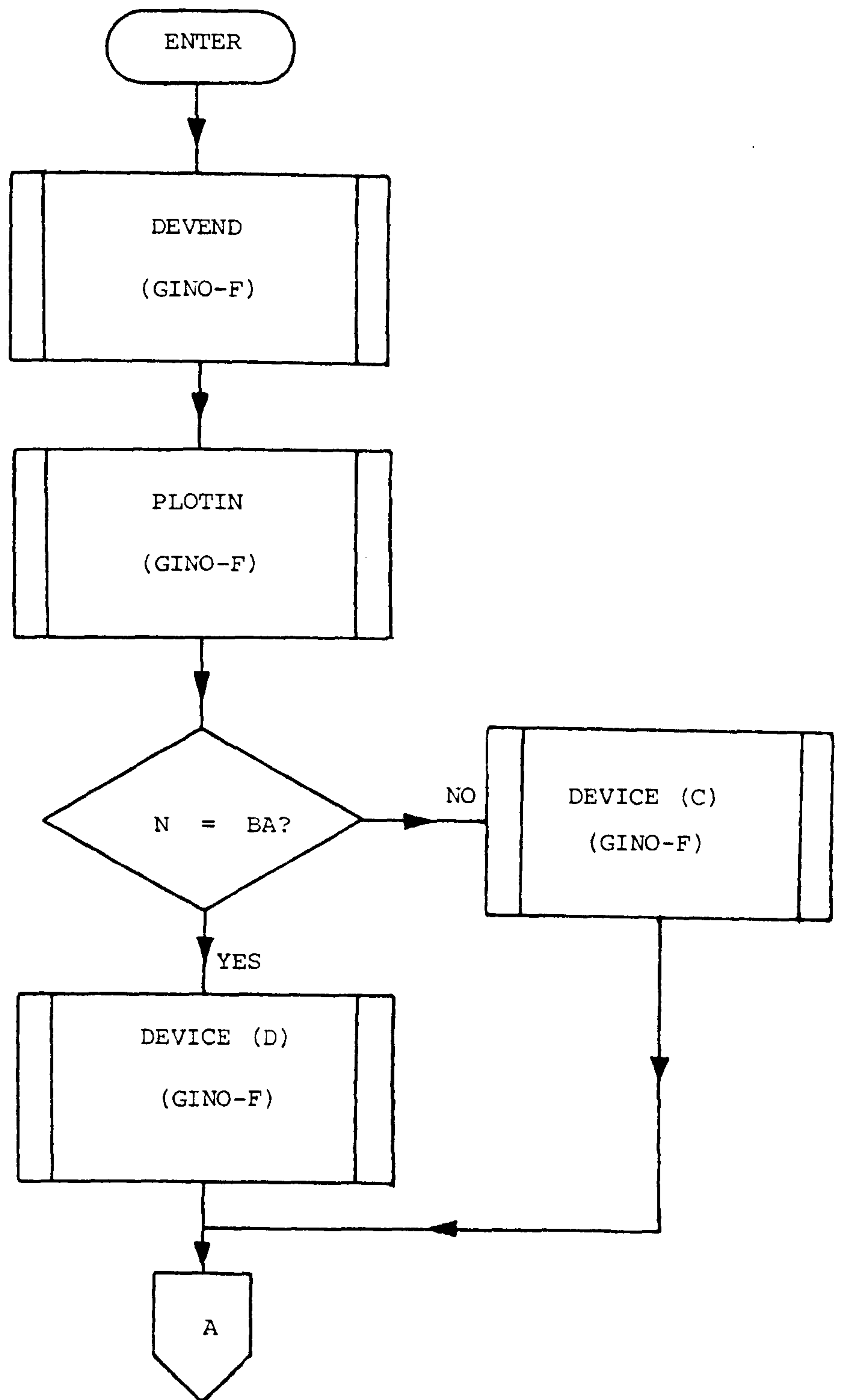


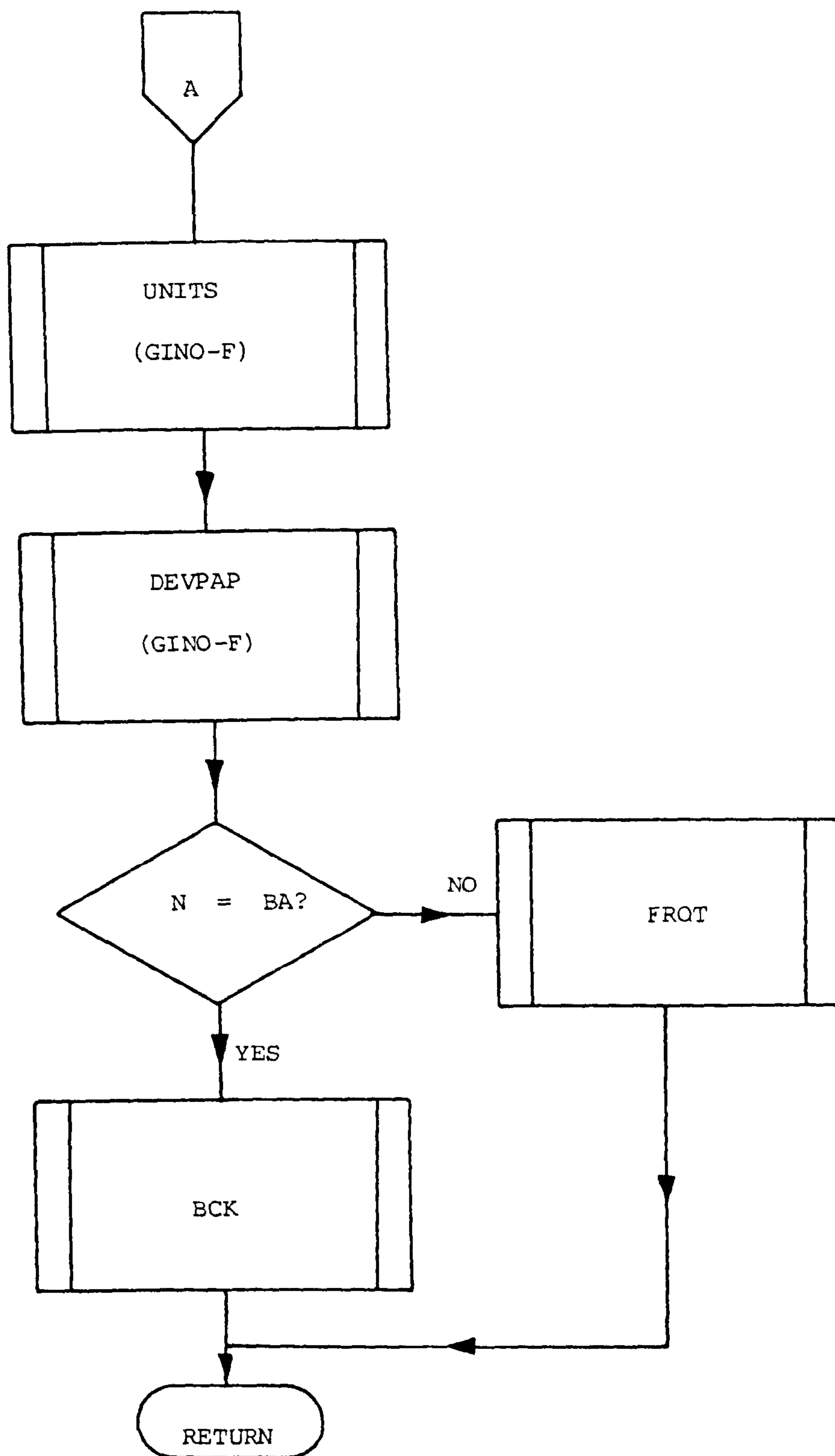


FLOW-CHART 19 : BLOCK ROUTINE

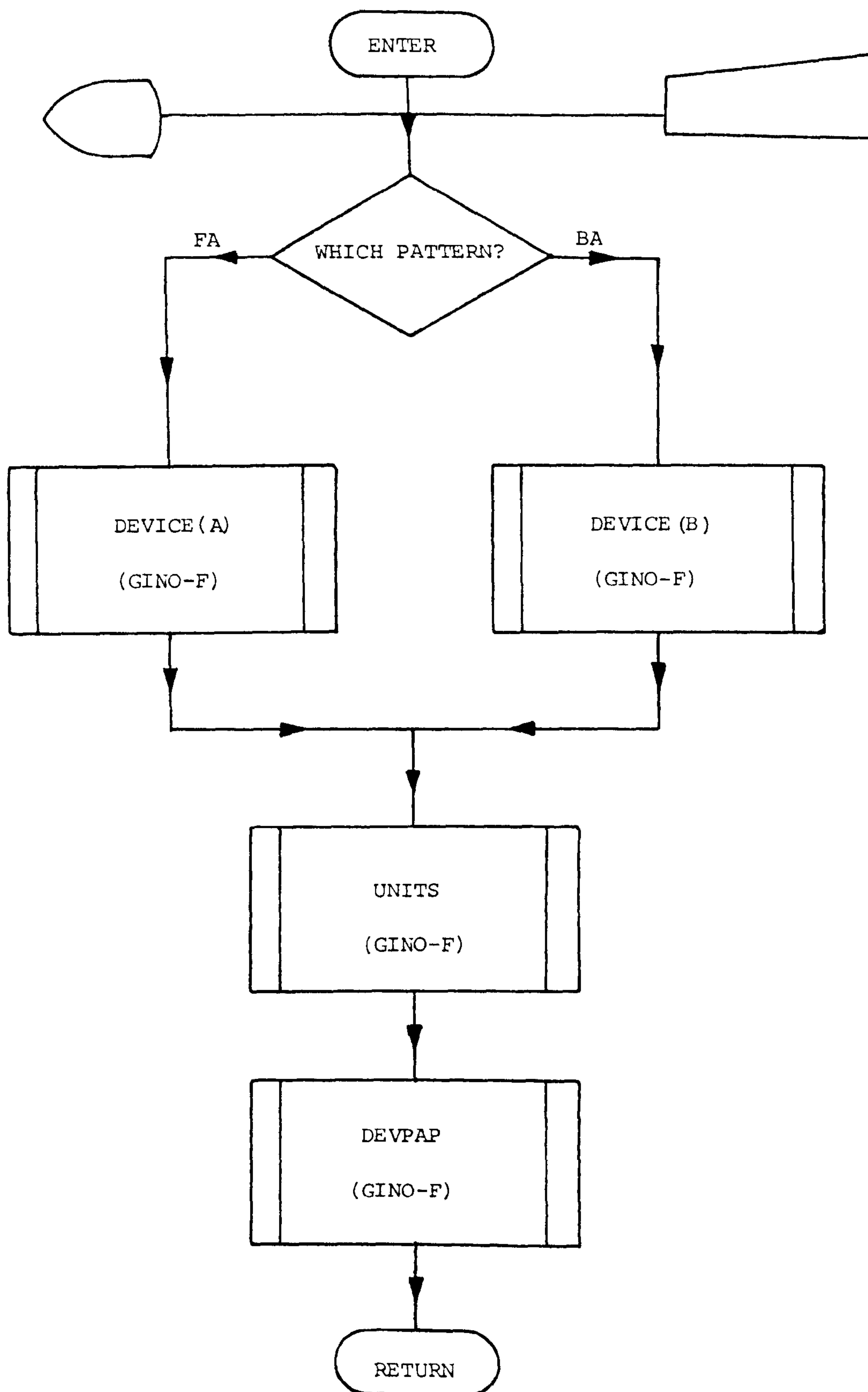


FLOW-CHART 20 : BLOCKA ROUTINE





FLOW-CHART 21 : PLOT ROUTINE



10.3.3.6 Drawing and Plotting Module

The purpose of this section is to provide the facilities to draw and plot the patterns required. It consists of a number of GINO-F sub-routines and was divided into four routines as follows:

(i) DRSKIN Routine

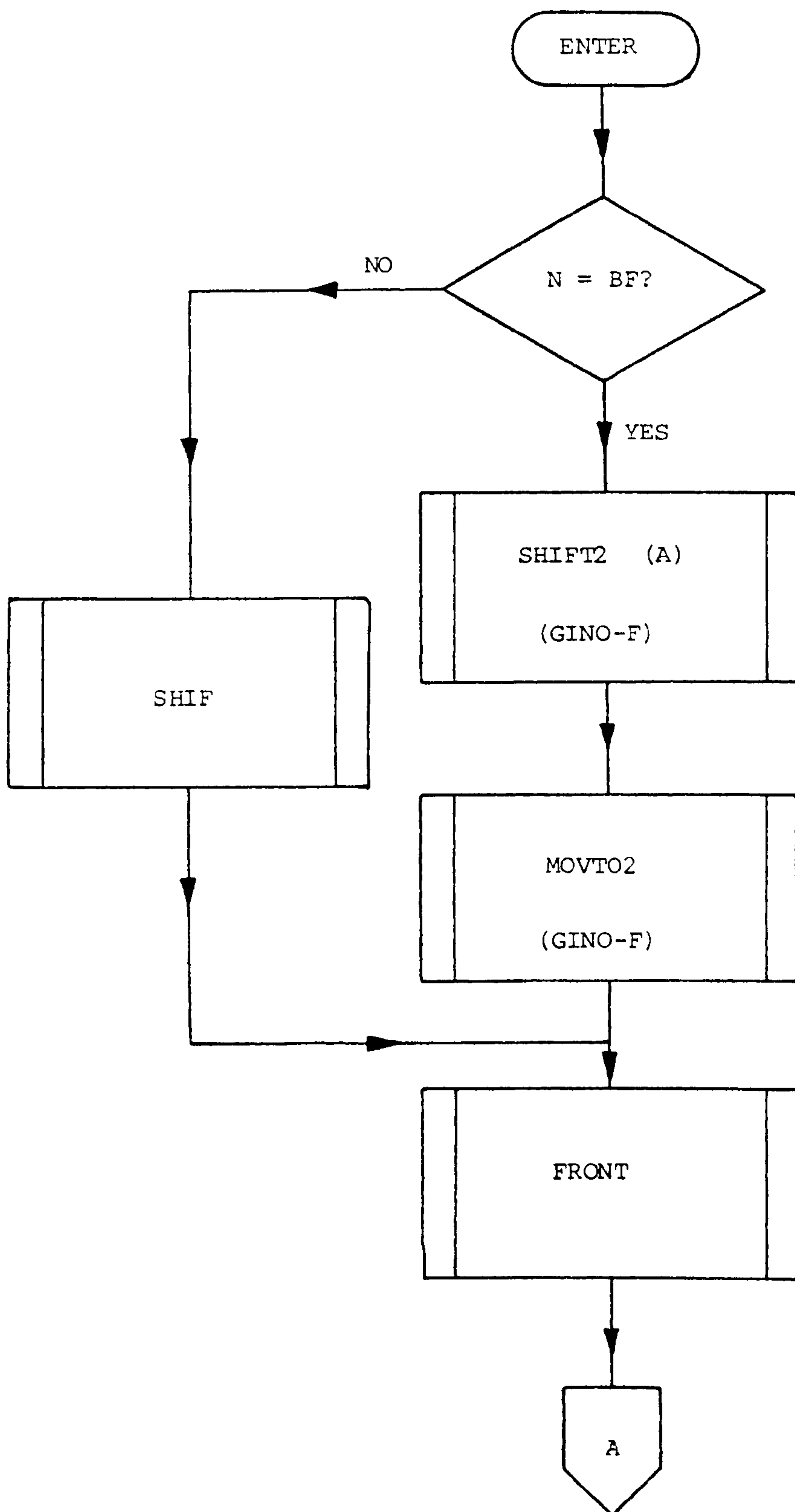
This routine was designed to draw the skin pattern. It consists of a number of GINO-F sub-routines and makes use of the data files provided by the calculation section. Initially, it calls the SHIF sub-routine which allocates the precise area of drawing and the place of the initial origin. Then, FRONT sub-routine is called which reads the co-ordinates for the front pattern and draws it on the screen.

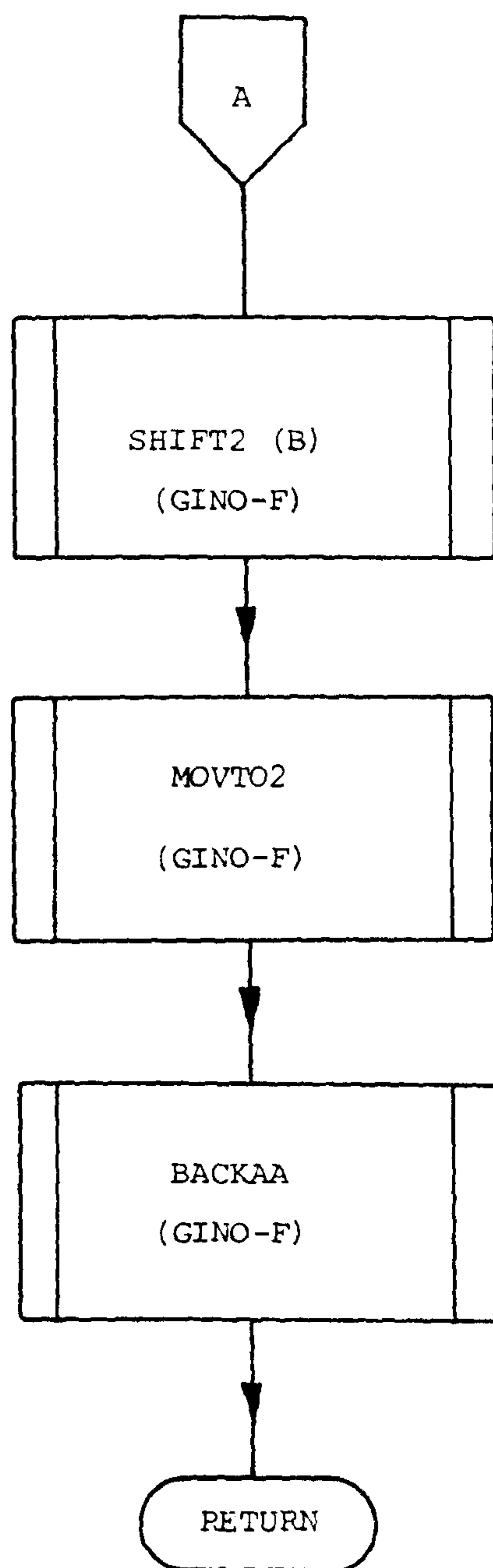
Upon completion of the front pattern drawing, the routine identifies the initial origin for the back pattern, calls the 'BACKAA' sub-routine which reads the back co-ordinates for a skin pattern and draws it on the screen. (See flow chart 22).

(ii) DRBLOK Routine

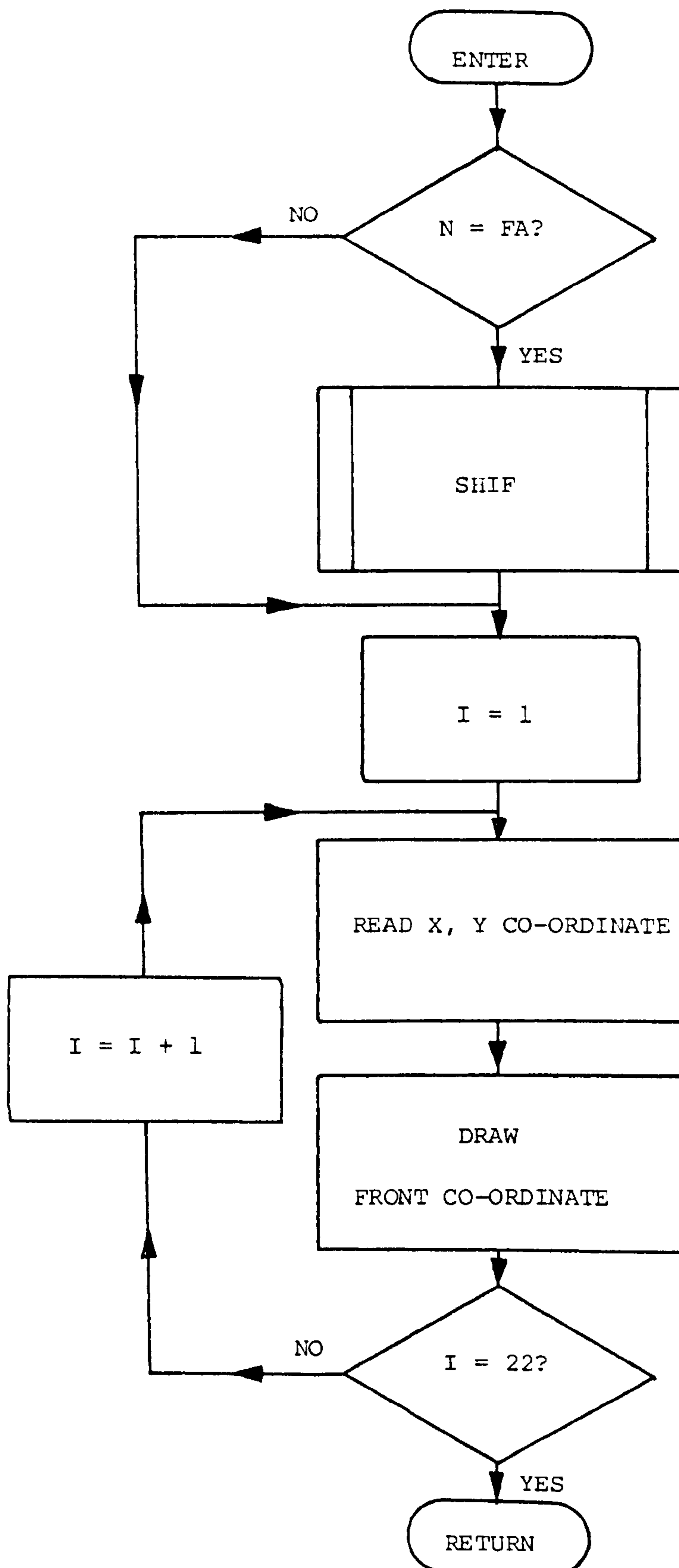
The purpose of this routine is to draw the block pattern on the screen. As in previous routine DRSKIN, the DRBLOK routine calls the SHIF sub-routine, which identifies the initial origin and then calls the FRONTA sub-routine, which superimposes the front block pattern on the front skin pattern already on the screen. After the front block pattern has been drawn the routine identifies the initial origin for the back block pattern and then calls the 'BACKA' sub-routine which superimposes the back block pattern on the back skin pattern already on the screen. Upon completion of this routine, both the skin and block patterns are shown on the screen. (See flow chart 25).

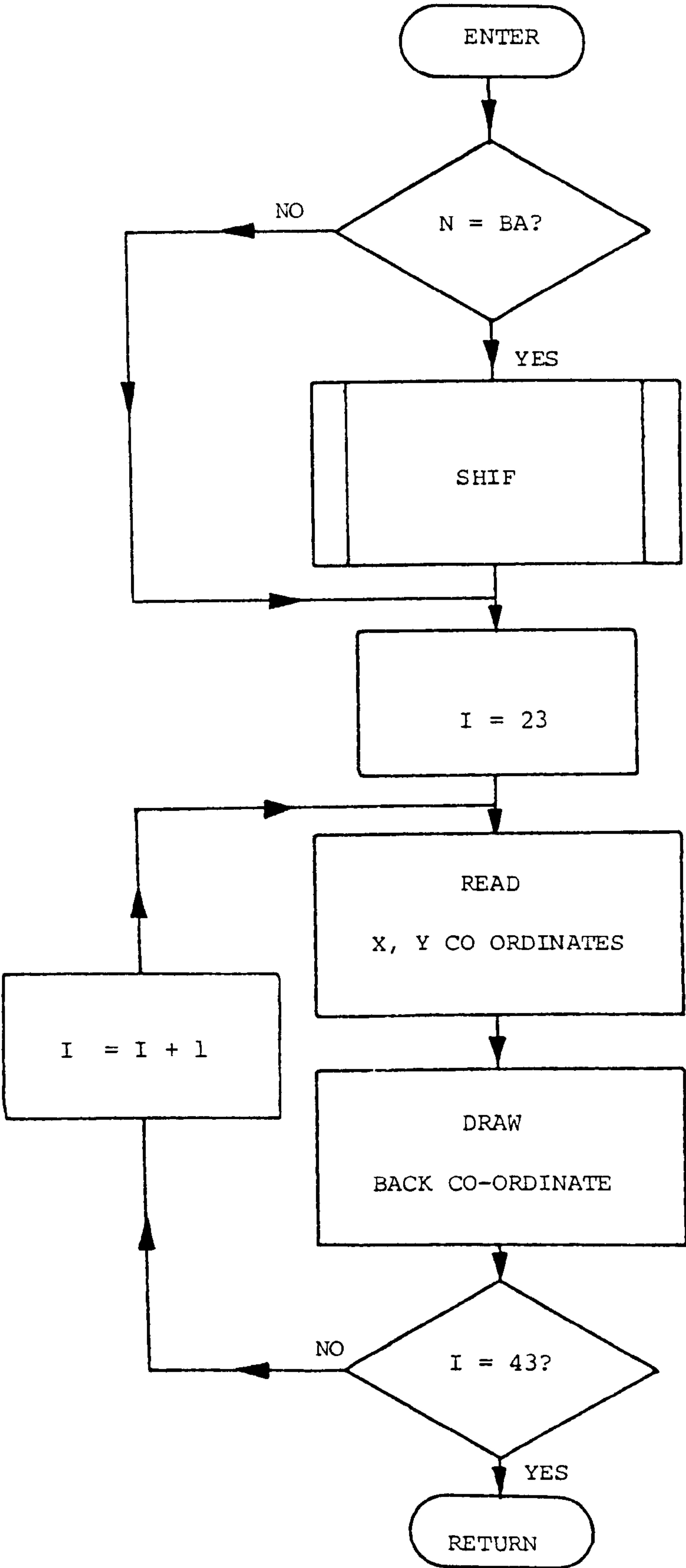
FLOW-CHART 22 : DRSKIN ROUTINE



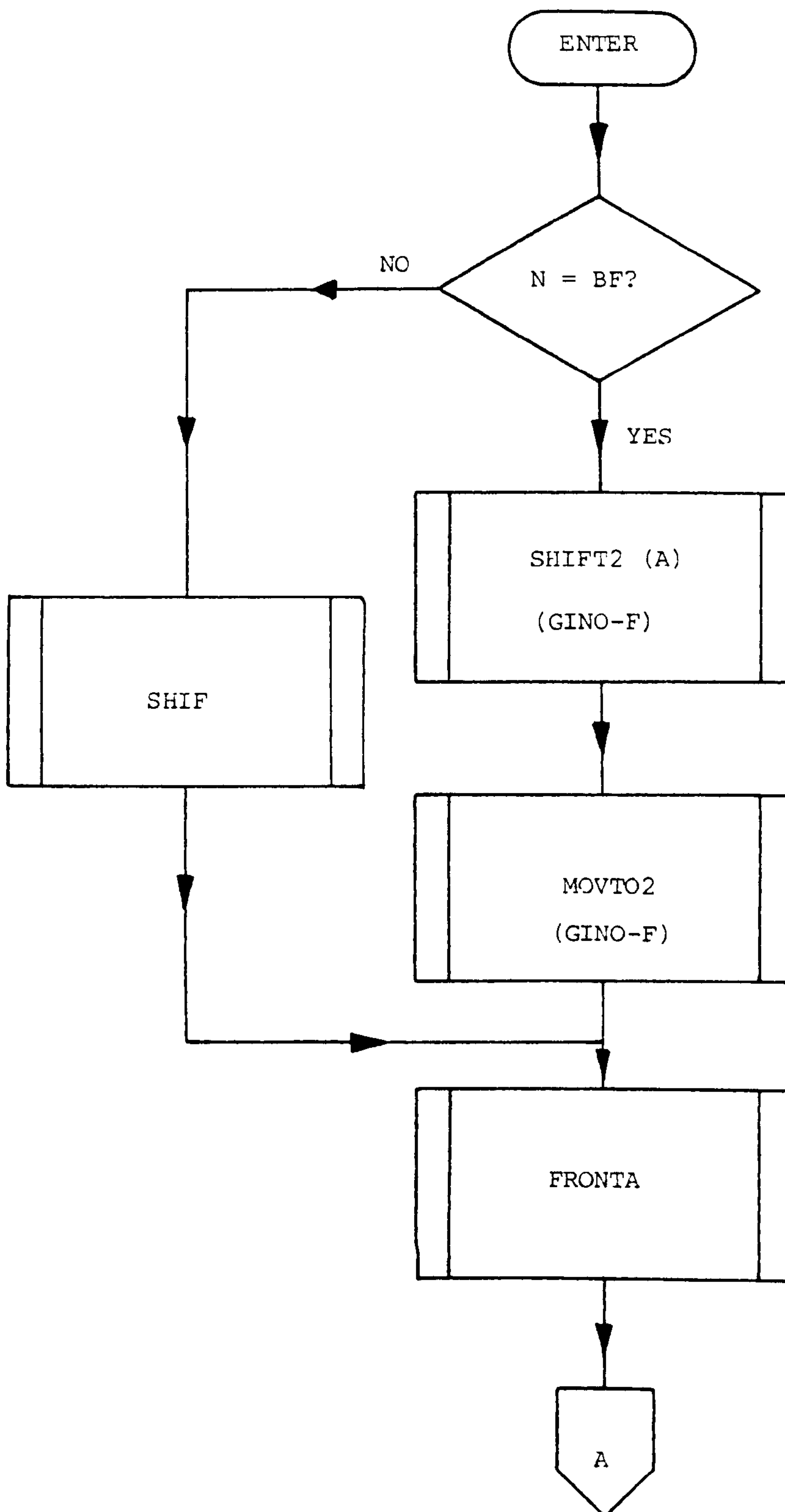


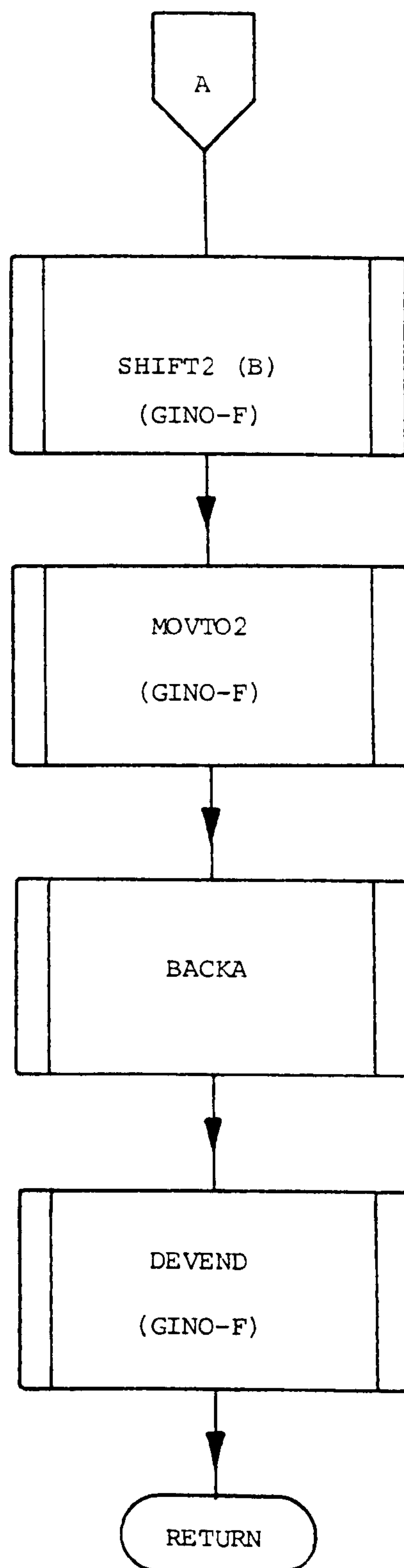
FLOW-CHART 23 : FRONT SUB-ROUTINE



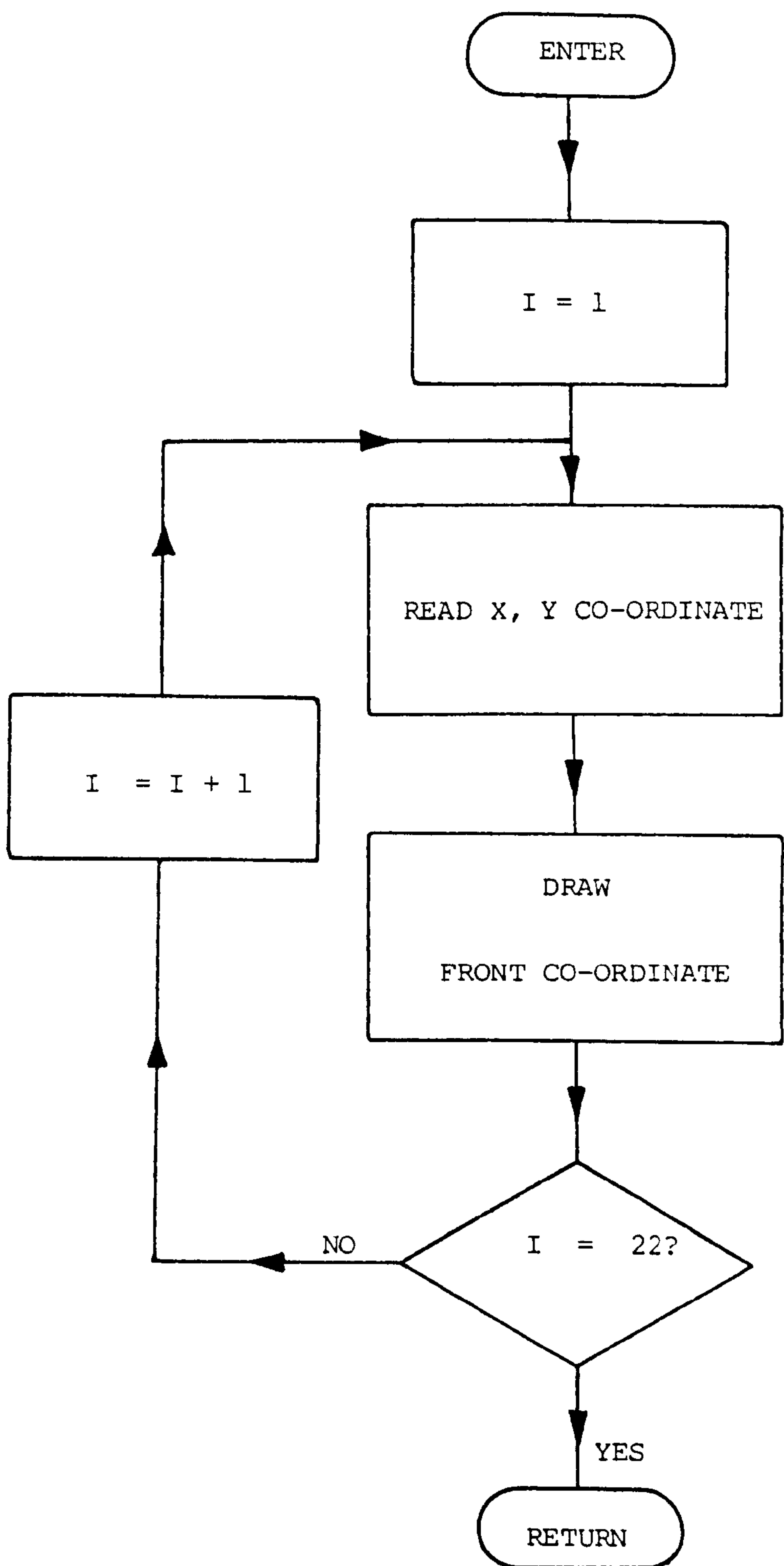


FLOW-CHART 25 : DRELOK ROUTINE

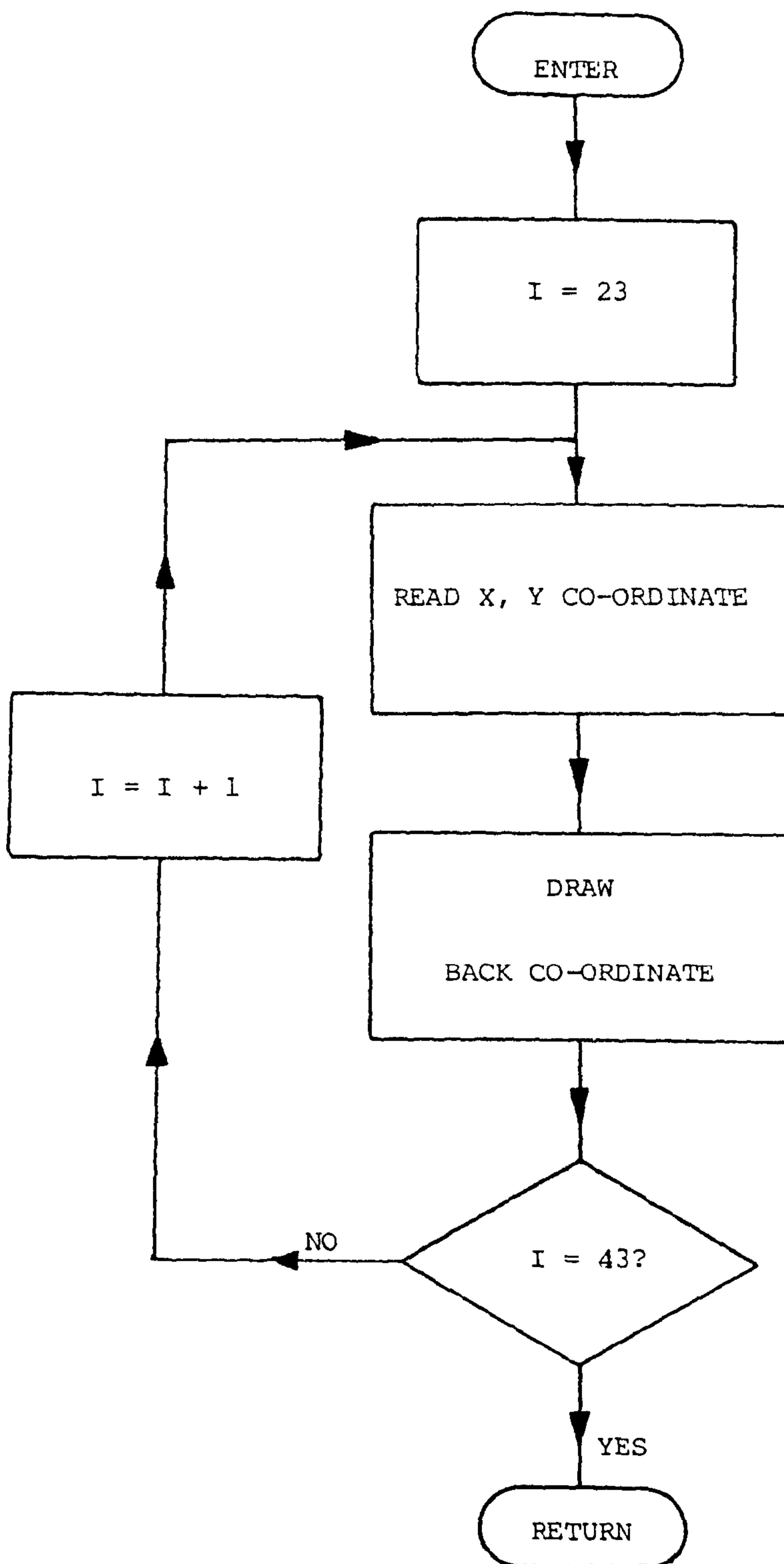




FLOW-CHART 26 : FRONTA SUB-ROUTINE



FLOW-CHART 27 : BACKA SUB-ROUTINE



As may be noticed, the DRSKIN and DRBLOK routines provide the drawing of skin and block patterns only on the screen and are available only for the 'BF' option. If a different option or plot is required, the following sub-routines are available.

(iii) FROand FROTSub-routines

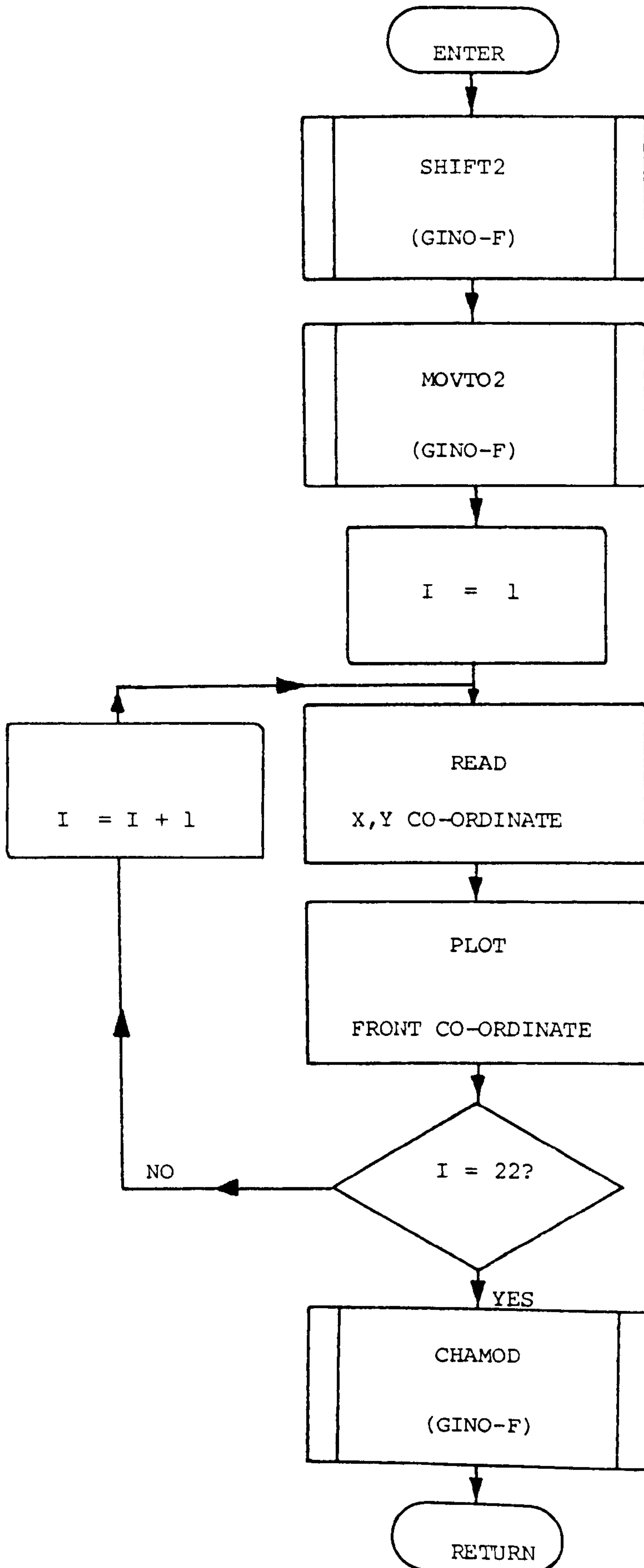
These sub-routines provide the means by which a front pattern (the FA option) may either be plotted by the plotter, or drawn on the screen. If either of the two are required this routine identifies the initial origin for the plotting area, reads the appropriate co-ordinates and either plots or shows the front pattern.

(iv) BCK or BAK Routines

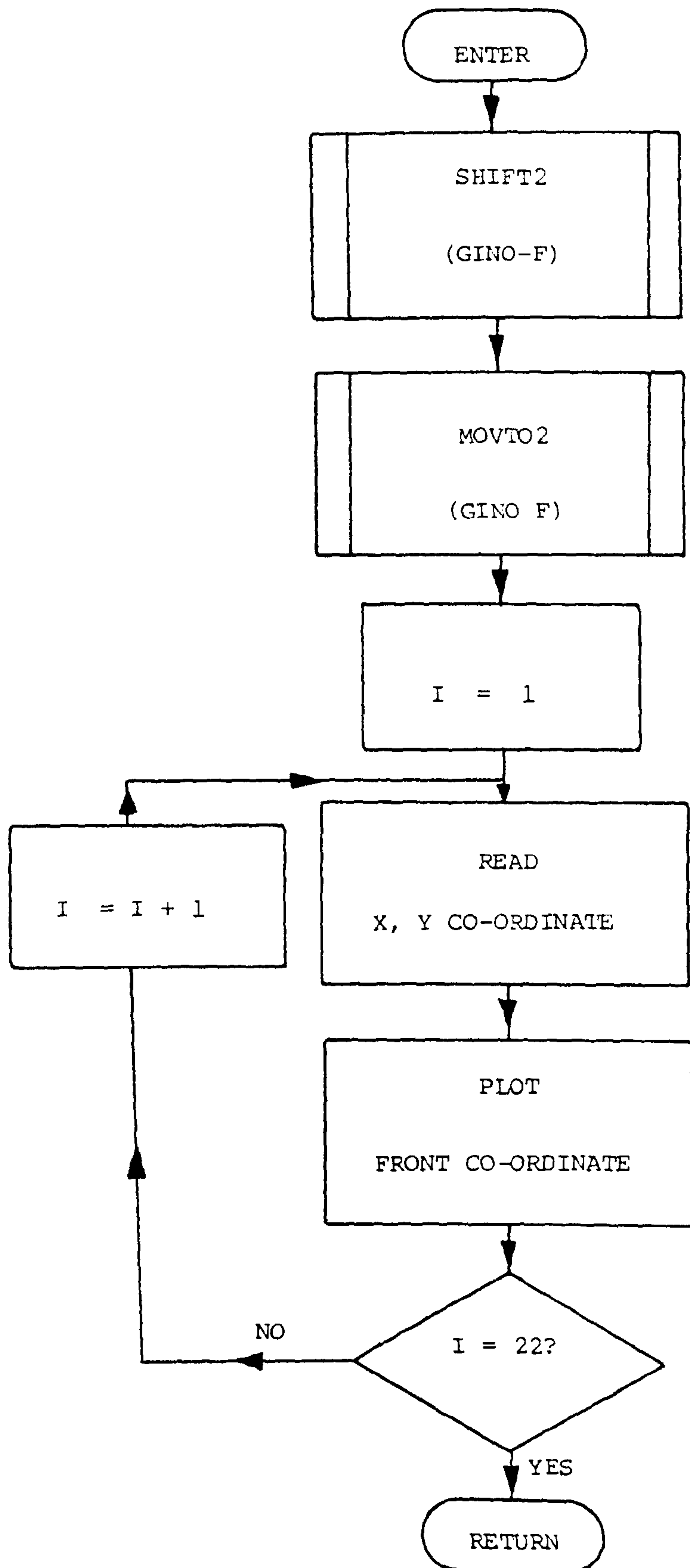
These routines provide the means by which a back panel (the BA option) may either be drawn or plotted. If either a plot or a drawing is required, the routine identifies the initial origin, reads the appropriate co-ordinates and either draws or plots the back pattern.

The structures of these routines are illustrated in the following flow charts.

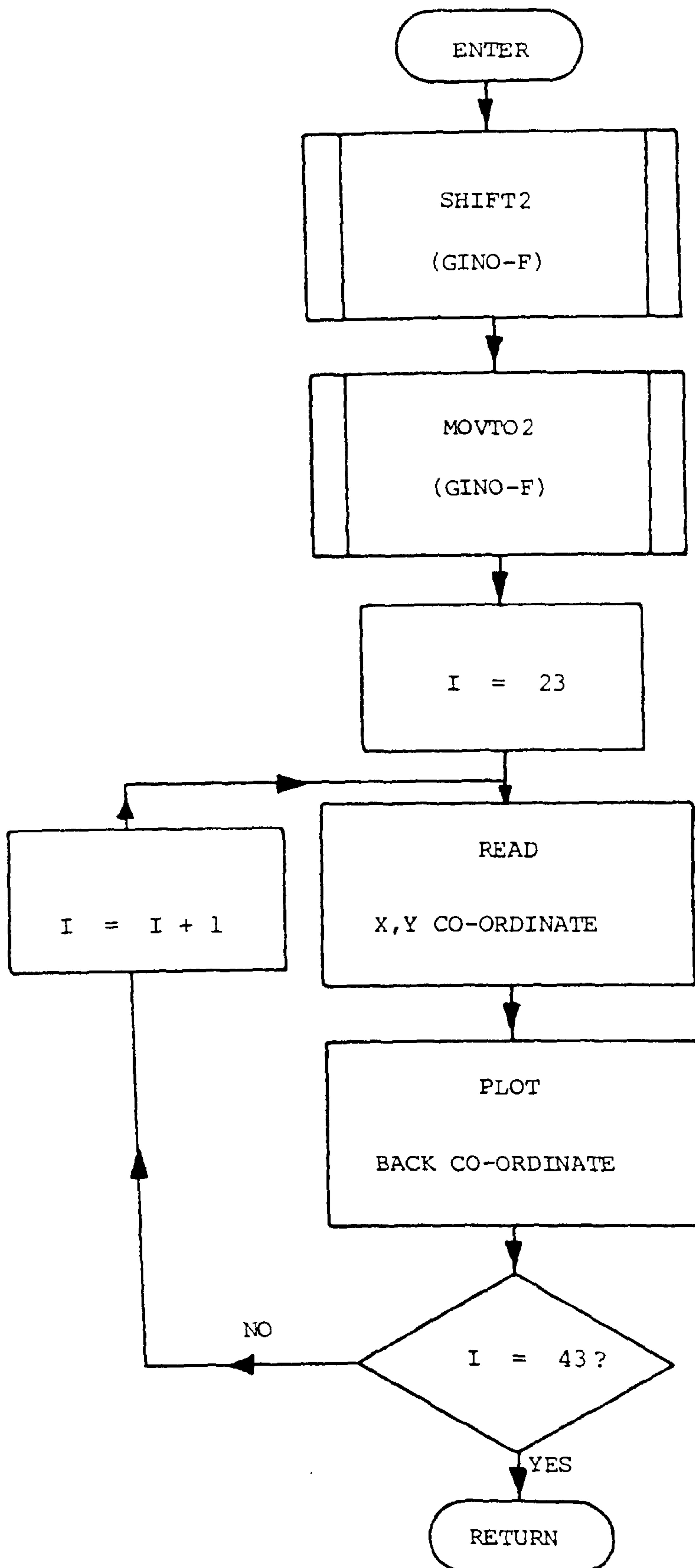
FLOW-CHART 28 : FRO ROUTINE



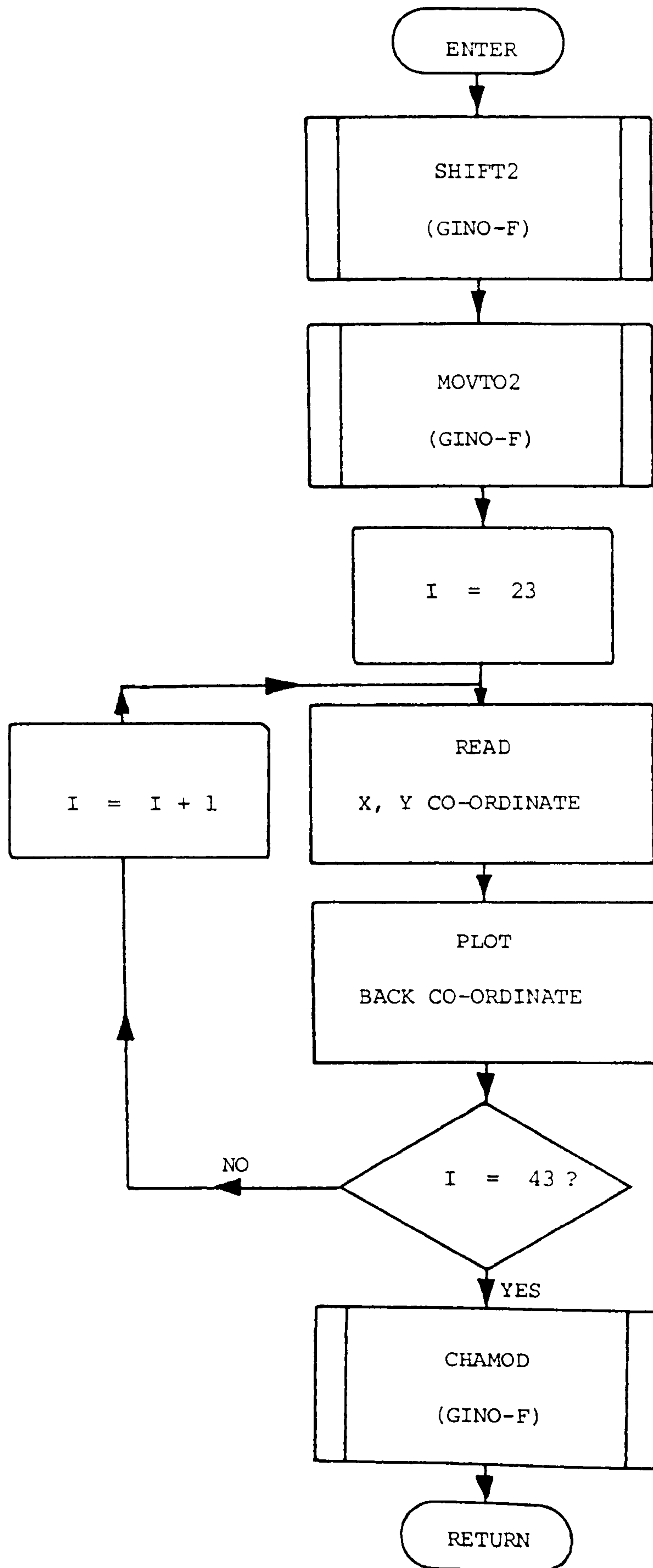
FLOW-CHART 29 : FROT ROUTINE



FLOW-CHART 30 : BCK ROUTINE



FLOW-CHART 31 : BAK ROUTINE



Upon completion of developing the software described in this chapter, it was felt that a test was necessary to find whether the software provides the appropriate information and if an accurate pattern is obtained. Thus, the three-dimensional co-ordinates obtained from measuring the cone (which was described in chapter seven), were fed into the system. The results obtained are the ones given in tables two and three in the same chapter seven.

The accuracy of the software is thus exemplified by the obviously accurate fit of the pattern on the cone shown in fig. 27c.

Several more examples of the use of these computer programs are given in the next part of this thesis where the results obtained from these programs are applied to obtain well shaped pattern pieces that when sewn together and put on the body measured, will ensure a garment of satisfactory fit.

PART C

THE EXPERIMENTAL WORK

CHAPTER ELEVEN

EXPERIMENTAL DETAILS

11.1 INTRODUCTION

As may be observed from the arguments presented so far, the ability to sell garments depends mostly on the quality of their fit. It has equally been observed that the traditional method of measuring the human figure, which uses the tape measure, and the method of constructing and drafting patterns based on these measurements, is far from accurate and will not provide the well shaped pattern pieces necessary to ensure a garment of satisfactory fit.

To overcome these problems, the method described in the previous chapters has been proposed to provide the necessary accuracy and speed to produce garments of satisfactory fit.

This method consists essentially of :

- (i) measuring the three-dimensional co-ordinates of crucial shaping points selected on each of the body panels.
- (ii) Feeding this information into the computer system will give:
 - (a) the distances between these points.
 - (b) the angles radiating around the apex point of each panel.
 - (c) the angle of dart needed to be inserted into the pattern.
 - (d) the two dimensional co-ordinates needed in order to plot a skin pattern.
 - (e) a well shaped (full size) skin pattern.
 - (f) if requested, a well shaped block pattern, that when sewn into a garment will fit perfectly the body measured.

The work described in this part was designed to investigate the validity of the method, the accuracy that may be achieved thereby and to attempt to assess the commercial value and significance of this new approach to the obtaining of garments of accurate and satisfactory fit.

Experimentally, the three-dimensional co-ordinates of the crucial shaping points were obtained using a workroom stand rather than a live model. Although, as previously mentioned, the workroom stand is not an exact replica of the human body and cannot therefore be regarded as an 'average' figure for its size, it was decided to use it rather than a human body for the experimental work because, given the measuring device described in Chapter eight, it was felt that inaccuracies, when measuring a human would arise as a result of the person not being able to remain still throughout the measuring process. This feature was obviously an essential one in attempting to assess the validity of the process and procedure.

Thus, the Kennett and Lindsell stand for a normal figure, a stand which is widely used in the bulk-manufacturing clothing industry was chosen and used as the basic figure.

11.2 EXPERIMENTAL DETAILS OF THE THREE DIMENSIONAL MEASUREMENTS OF THE HUMAN FIGURE

In order to experimentally investigate the new proposed method, it was necessary to measure the three-dimensional co-ordinates of the crucial shaping points accurately and reliably. After obtaining these accurate three-dimensional co-ordinates, this information was fed into the computer system, which in turn plotted a full size skin pattern based on these co-ordinates (if requested a full size block pattern could also be plotted). To confirm the findings over a range of basic body figures, it was decided to produce patterns for the following range of stand sizes - 10, 12, 14 and 16.

The results obtained by the computer program for both front and back panels of each size give the following information:

- (i) the three-dimensional co-ordinates of the crucial shaping points selected for the front panel.
- (ii) the three-dimensional co-ordinates of the crucial shaping points selected for the back panel.
- (iii) the linear and curved distances between the apex point and the crucial shaping points.
- (iv) the linear and curved distances between the crucial shaping points.
- (v) the angles that each of the triangular sections make at the apex point.
- (vi) the angle of dart divided into upper and lower parts.
- (vii) the two dimensional co-ordinates from which a skin pattern may be plotted.
- (viii) the two dimensional co-ordinates from which a block pattern may be plotted.

In addition, the computer was required to plot the full size skin and block pattern pieces for each of the four sizes measured.

The following tables contain this information and are grouped as follows:

- (i) Table 4 (i) - (viii) provides the information for size 10.
- (ii) Table 5 (i) - (viii) provides the information for size 12.
- (iii) Table 6 (i) - (viii) provides the information for size 14.
- (iv) Table 7 (i) - (viii) provides the information for size 16.

The shape of the skin and block patterns for each of the above are given at $\frac{1}{3}$ scale in Figs. 43 - 46.

SIZE 10				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Bust prominence point	8.80	37.00	25.00
2	Between bust prominence	0.00	37.00	23.00
3	Mid front point	0.00	49.00	17.80
4	Neck point	0.00	54.00	16.20
5	Mid neck point	4.00	56.00	15.00
6	Shoulder/neck point	6.50	60.50	12.00
7	Mid shoulder point	12.00	58.50	12.00
8	End of shoulder	18.00	56.00	11.50
9	Mid upper armhole point	17.50	52.00	14.00
10	Mid armhole point	17.50	49.00	16.50
11	Mid lower armhole	16.50	44.00	16.00
12	Underarm point	16.00	42.00	12.00
13	Bustline point	14.70	37.00	12.00
14	Dart point on sideseam	13.20	29.50	12.00
15	Waist-side point	14.00	21.50	12.00
16	Mid-waist point	6.50	21.50	19.00
17	Centre waist point	0.00	21.50	19.50

TABLE 4(i)

Three-dimensional co-ordinates of crucial shaping points.
 Front panel.
 Co-ordinates in cm.

SIZE 10				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Shoulder blade	12.00	50.40	3.50
2	Mid-back point	0.00	50.40	4.00
3	Cervical point	0.00	61.50	8.50
4	Mid-neck point	4.00	61.50	9.00
5	Shoulder/neck point	6.50	60.50	12.00
6	Mid-shoulder point	12.00	58.50	12.00
7	End of shoulder	18.00	56.00	11.50
8	Mid-upper armhole point	17.50	52.00	8.00
9	Mid armhole	17.25	49.50	6.00
10	Mid-lower armhole point	17.00	46.00	6.00
11	Underarm point	16.00	42.00	12.00
12	Bustline point	14.70	37.00	12.00
13	Dart point at sideseam	13.20	29.50	12.00
14	Waist-side point	14.00	21.50	12.00
15	Mid-waist point	7.00	21.50	7.00
16	Centre waist point	0.00	21.50	6.80

TABLE 4(ii)
 Three-dimensional co-ordinates of crucial shaping points.
 Back panel.
 Co-ordinates in cm.

SIZE 10				
Point No.	FRONT	BACK		
	Linear Distance	Linear Distance	Curvature Factor	Curved Distance
1	-	-	-	-
2	9.02	12.01	1.00	12.01
3	16.53	17.09	1.00	17.09
4	21.07	14.75	1.00	14.75
5	22.00	14.30	1.00	14.30
6	26.95	11.74	1.00	11.74
7	25.33	11.46	1.00	11.46
8	25.06	7.28	1.00	7.28
9	20.54	5.88	1.00	5.88
10	17.09	7.11	1.00	7.11
11	13.79 6 ⁱ	12.60	1.11	13.99
12	15.68	16.10	1.09	17.55
13	14.28	22.59	1.02	23.05
14	15.64	30.19	1.01	30.49
15	20.89	29.54	1.02	30.13
16	16.78	31.47	1.00	31.47
17	18.65			

TABLE 4(iii)

Linear and curved distances between apex point and crucial shaping points.

Distances in cm.

SIZE 10					
Front			Back		
Point No.	Distance	Angle	Point No.	Distance	Angle
2 - 3	13.08	0.91	2 - 3	11.98	0.78
3 - 4	5.25	0.14	3 - 4	4.03	0.21
4 - 5	4.63	0.21	4 - 5	4.03	0.28
5 - 6	5.96	0.14	5 - 6	5.85	0.41
6 - 7	5.85	0.22	6 - 7	6.52	0.57
7 - 8	6.52	0.26	7 - 8	5.34	0.37
8 - 9	4.74	0.06	8 - 9	3.21	0.45
9 - 10	3.91	0.10	9 - 10	3.51	0.51
10 - 11	5.12	0.25	10 - 11	7.28	0.24
11 - 12	4.5	0.28	11 - 12	5.17	0.24
12 - 13	5.17	0.33	12 - 13	7.65	0.27
13 - 14	7.65	0.51	13 - 14	8.04	0.11
14 - 15	8.04	0.34	14 - 15	8.6	0.28
15 - 16	10.26	0.51	15 - 16	7.0	0.22
16 - 17	6.52	0.35	16 - 2	29.04	1.18
17 - 2	15.89	1.02			
Upper Part		0.24	Upper Part		0.09
Lower Part		0.41	Lower Part		0.08
Angle of full dart (ϵ)		0.65	Angle of dart (ϵ)		0.17

TABLE 4(iv), (v) and (vi)

Distances and angles between crucial shaping points and angle of dart.

Distances in cm.

Angles in Radians.

SIZE 10				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	9.02	0.00	12.01	0.00
3	10.18	13.03	12.20	11.98
4	10.50	18.27	8.18	12.27
5	6.72	20.95	4.38	13.61
6	4.68	26.55	-1.15	11.69
7	-1.04	25.31	0.00	0.00
8	0.00	0.00	-2.21	11.53
9	-7.06	24.32	-7.88	8.32
10	-12.92	21.47	-6.57	3.15
11	-11.68	16.89	-5.88	0.01
12	-10.42	13.04	-6.20	-3.49
13	-11.25	7.92	-10.21	-9.56
14	-14.81	5.16	-9.59	-14.69
15	-14.28	0.02	-7.10	-21.93
16	-13.67	-7.60	-6.02	-29.89
17	-13.85	-15.64	2.58	-30.02
18	-3.61	-16.39	0.00	0.00
19	0.00	0.00	5.06	-29.70
20	3.25	-16.46	12.03	-29.07
21	9.75	-15.90	12.01	-0.04
22	9.02	-0.03		

TABLE 4(vii)

Two-dimensional co-ordinates for plotting a skin pattern.

Co-ordinates in cm.

SIZE 10				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	9.72	0.00	12.01	0.00
3	10.35	13.03	12.02	12.29
4	10.50	18.27	8.18	12.51
5	6.72	20.95	4.38	13.88
6	4.68	26.78	-1.17	11.92
7	-1.04	25.53	-0.60	3.70
8	-0.35	2.50	-2.25	11.76
9	-0.12	24.53	-8.35	8.32
10	-13.43	21.66	-6.89	2.80
11	-11.41	16.38	-6.40	0.02
12	-10.73	12.77	-6.20	-3.49
13	-11.25	7.92	-10.80	-10.89
14	-15.43	3.76	-10.80	-10.89
15	-15.43	3.76	-10.80	-10.89
16	-15.43	3.76	-6.65	-29.89
17	-14.48	-15.65	2.58	-30.20
18	-3.35	-16.39	0.40	-3.70
19	0.00	-2.50	5.06	-29.70
20	2.79	-16.46	12.03	-29.07
21	9.75	-15.90	12.01	-0.04
22	9.72	-0.03		

TABLE 4(viii)

Two-dimensional co-ordinates for plotting a block pattern.

Co-ordinates in cm.

SIZE 12				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Bust prominence point	10.50	37.20	25.00
2	Between bust prominence	0.00	37.20	23.20
3	Mid front point	0.00	48.10	21.20
4	Neck point	0.00	54.30	18.00
5	Mid neck point	4.70	55.00	16.00
6	Shoulder/neck point	6.40	59.50	12.00
7	Mid shoulder point	11.40	57.10	12.20
8	End of shoulder	17.80	55.30	12.50
9	Mid upper armhole point	16.00	51.50	15.50
10	Mid armhole point	15.80	48.50	17.00
11	Mid lower armhole	14.50	43.00	14.00
12	Underarm point	16.20	42.00	13.00
13	Bustline point	15.20	37.20	13.00
14	Dart point on sideseam	13.40	28.00	13.00
15	Waist-side point	12.00	21.00	13.00
16	Mid-waist point	7.50	21.00	18.75
17	Centre waist point	0.00	21.00	22.00

TABLE 5(i)

Three-dimensional co-ordinates of crucial shaping points.

Front panel.

Co-ordinates in cm.

SIZE 12				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Shoulder blade	11.50	50.10	4.50
2	Mid-back point	0.00	50.10	5.50
3	Cervical point	0.00	61.50	8.00
4	Mid-neck point	4.00	60.50	10.00
5	Shoulder/neck point	6.40	59.50	12.00
6	Mid-shoulder point	11.40	57.10	12.20
7	End of shoulder	17.80	55.30	12.50
8	Mid-upper armhole point	17.50	53.20	10.00
9	Mid armhole	17.00	49.00	8.00
10	Mid-lower armhole point	16.50	43.50	12.00
11	Underarm point	16.20	42.00	13.00
12	Bustline point	15.20	37.20	13.00
13	Dart point at sideseam	13.40	28.00	13.00
14	Waist-side point	12.00	21.00	13.00
15	Mid-waist point	8.50	21.00	7.50
16	Centre waist point	0.00	21.00	6.00

TABLE 5(ii)

Three-dimensional co-ordinates of crucial shaping points.

Back panel.

Co-ordinates in cm.

SIZE 12				
Point No.	FRONT	BACK		
	Linear Distance	Linear Distance	Curvature Factor	Curved Distance
1	-	-	-	-
2	10.65	11.54	1.00	11.54
3	15.60	16.57	1.00	16.57
4	21.25	13.95	1.00	13.95
5	20.77	13.06	1.00	13.06
6	26.14	10.41	1.03	10.72
7	23.68	11.43	1.00	11.43
8	23.18	8.71	1.00	8.71
9	18.03	6.61	1.00	6.61
10	14.82	11.17	1.00	11.17
11	13.06	12.65	1.10	13.91
12	14.13	15.89	1.07	16.99
13	12.89	23.75	1.01	23.98
14	15.40	30.32	1.01	30.62
15	20.22	29.41	1.00	29.41
16	17.62	31.33	1.00	31.33
17	19.54			

TABLE 5(iii)

Linear and curved distances between apex point and crucial shaping points.

Distances expressed in cm.

SIZE 12					
Front			Back		
Point No.	Distance	Angle	Point No.	Distance	Angle
2 - 3	11.08	0.79	2 - 3	11.79	0.78
3 - 4	6.89	0.23	3 - 4	4.58	0.25
4 - 5	5.16	0.24	4 - 5	3.28	0.23
5 - 6	6.26	0.14	5 - 6	5.55	0.43
6 - 7	5.55	0.20	6 - 7	6.66	0.61
7 - 8	6.66	0.28	7 - 8	3.28	0.18
8 - 9	5.17	0.02	8 - 9	4.68	0.56
9 - 10	3.36	0.06	9 - 10	6.82	0.60
10 - 11	6.40	0.45	10 - 11	2.83*	0.07
11 - 12	2.21	0.14	11 - 12	4.90	0.25
12 - 13	4.90	0.35	12 - 13	9.37	0.31
13 - 14	9.37	0.65	13 - 14	7.14	0.10
14 - 15	7.14	0.30	14 - 15	6.10	0.20
15 - 16	7.30	0.36	15 - 16	8.63	0.28
16 - 17	8.17	0.43	16 - 2	29.12	1.19
17 - 2	16.24	0.98			
Upper part		0.24	Upper part		0.10
Lower part		0.42	Lower part		0.14
Full dart (ϵ)		0.66	Full dart (ϵ)		0.24

TABLE 5(iv), (v) and (vi)

Distances and angles between crucial shaping points and angle of dart.

Distances in cm.

Angles in Radians.

* including factor of 1.56 for body curvature

SIZE 12				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	10.65	0.00	11.54	0.00
3	10.99	11.08	11.76	11.67
4	11.22	18.05	7.19	11.96
5	6.36	19.77	3.94	12.45
6	4.50	25.75	-1.30	10.64
7	-0.65	23.67	0.00	0.00
8	0.00	0.00	-2.35	10.46
9	-6.10	22.88	-8.42	7.73
10	-12.01	19.82	-7.38	4.63
11	-9.65	15.23	-6.61	0.01
12	-8.70	12.00	-9.24	-6.28
13	-11.48	6.24	-10.99	-8.53
14	-13.24	4.91	-10.45	-13.41
15	-12.89	0.02	-8.26	-22.52
16	-12.25	-9.33	-7.70	-29.64
17	-11.75	-16.46	-1.18	-29.38
18	-4.47	-17.02	0.00	0.00
19	0.00	0.00	2.86	-29.27
20	2.71	-17.41	11.54	-29.14
21	10.80	-16.28	11.54	-0.04
22	10.65	-0.03		

TABLE 5(vii)

Two-dimensional co-ordinates for plotting askin pattern.

Co-ordinates in cm.

SIZE 12				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	11.05	0.00	11.54	0.00
3	11.19	11.08	11.76	12.00
4	11.22	18.05	7.19	12.31
5	6.36	19.77	3.94	12.79
6	4.50	25.98	-1.32	10.99
7	-0.65	24.23	-0.90	3.70
8	-0.40	2.50	-2.44	10.66
9	-6.18	23.20	-8.92	7.73
10	-12.49	19.82	-7.74	4.12
11	-9.72	14.77	-7.19	0.02
12	-8.95	11.76	-9.24	-6.28
13	-11.48	6.24	-11.64	-9.72
14	-13.80	3.58	-11.64	-9.72
15	-13.80	3.58	-11.64	-9.72
16	-13.80	3.58	-8.56	-29.64
17	-12.31	-16.46	-1.05	-29.38
18	-4.15	-17.02	0.10	-3.70
19	-0.10	-2.50	2.86	-29.27
20	2.11	-17.53	11.54	-29.14
21	10.80	-16.28	11.54	-0.04
22	11.05	-0.03		

TABLE 5(viii)

Two-dimensional co-ordinates for plotting a block pattern.

SIZE 14				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Bust prominence point	10.50	48.00	27.00
2	Between bust prominence	0.00	48.00	25.50
3	Mid front point	0.00	57.50	22.50
4	Neck point	0.00	65.50	19.00
5	Mid neck point	5.00	67.00	17.00
6	Shoulder/neck point	6.20	70.00	13.00
7	Mid shoulder point	11.50	67.50	13.00
8	End of shoulder	17.50	65.00	13.00
9	Mid upper armhole point	17.00	62.50	16.00
10	Mid armhole point	16.50	59.00	18.50
11	Mid lower armhole	17.00	53.00	16.50
12	Underarm point	17.00	50.50	14.00
13	Bustline point	16.70	46.00	14.00
14	Dart point on sideseam	14.70	39.00	14.00
15	Waist-side point	14.00	29.00	14.00
16	Mid-waist point	7.00	29.00	20.00
17	Centre waist point	0.00	29.00	21.00

TABLE 6(i)

Three-dimensional co-ordinates of crucial shaping points
 Front Panel.
 Co-ordinates in cm.

SIZE 14				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Shoulder blade	11.00	59.00	4.00
2	Mid-back point	0.00	59.00	3.00
3	Cervical point	0.00	70.50	9.00
4	Mid-neck point	3.50	70.00	9.50
5	Shoulder/neck point	6.20	70.00	13.00
6	Mid-shoulder point	11.50	67.50	13.00
7	End of shoulder	17.50	65.00	13.00
8	Mid-upper armhole point	16.50	63.00	9.00
9	Mid armhole	16.00	58.50	8.00
10	Mid-lower armhole point	16.50	56.00	8.00
11	Underarm point	17.00	50.50	14.00
12	Bustline point	16.70	46.00	14.00
13	Dart point at sideseam	14.70	39.00	14.00
14	Waist-side point	14.00	29.00	14.00
15	Mid-waist point	7.00	29.00	10.00
16	Centre waist point	0.00	29.00	6.50

TABLE 6(ii)

Three-dimensional co-ordinates of crucial shaping points.

Back panel.

Co-ordinates in cm.

SIZE 14				
Point No.	FRONT	BACK		
	Linear Distance	Linear Distance	Curvature Factor	Curved Distance
1	-	-	-	-
2	10.61	11.05	1.00	11.05
3	14.86	16.68	1.00	16.68
4	21.92	14.40	1.00	14.40
5	22.16	15.00	1.00	15.00
6	26.43	12.39	1.00	21.39
7	24.03	12.62	1.00	12.62
8	23.11	8.44	1.00	8.44
9	19.33	6.42	1.05	6.74
10	15.14	7.43	1.05	7.80
11	13.32	14.43	1.05	15.15
12	14.75	17.36	1.04	18.06
13	14.54	22.66	1.00	22.66
14	16.36	31.76	1.00	31.76
15	23.29	30.85	1.00	30.85
16	20.55	32.05	1.00	32.05
17	22.52			

TABLE 6(iii)

Linear and curved distances between apex point and crucial shaping points.

Distances in cm.

SIZE 14					
Front			Back		
Point No.	Distance	Angle	Point No.	Distance	Angle
2 - 3	9.96	0.73	2 - 3	12.97	0.89
3 - 4	8.73	0.29	3 - 4	3.57	0.18
4 - 5	5.59	0.25	4 - 5	4.42	0.30
5 - 6	5.14	0.12	5 - 6	5.86	0.39
6 - 7	5.86	0.21	6 - 7	7.83	0.53
7 - 8	6.50	0.27	7 - 8	4.58	0.18
8 - 9	3.94	0.05	8 - 9	4.64	0.58
9 - 10	4.33	0.06	9 - 10	2.55	0.32
10 - 11	6.34	0.43	10 - 11	8.15	0.33
11 - 12	3.54	0.23	11 - 12	4.51	0.21
12 - 13	4.51	0.31	12 - 13	7.28	0.28
13 - 14	7.28	0.46	13 - 14	10.02	0.16
14 - 15	10.02	0.37	14 - 15	9.34	0.30
15 - 16	10.14*	0.45	15 - 16	7.83**	0.25
16 - 17	7.07	0.32	16 - 2	30.20	1.23
17 - 2	19.03	1.05			
Upper part		0.17	Upper part		0.10
Lower part		0.49	Lower part		0.07
Angle of full dart(ε)		0.66	Angle of full dart(ε)		0.17

TABLE 6(iv), (v) and (vi)

Distances and angles between crucial shaping points
and angle of dart.

Distances in cm. Angles in radians.

* including factor of 1.01 for body curvature.

** including factor of 1.15 for body curvature.

SIZE 14				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	10.61	0.00	11.05	0.00
3	11.03	9.95	10.50	12.96
4	11.48	18.67	6.95	12.62
5	6.49	21.19	3.04	14.69
6	4.69	26.01	-2.25	12.18
7	-0.82	24.01	0.00	0.00
8	0.00	0.00	-3.44	11.90
9	-4.94	23.51	-9.11	8.73
10	-10.69	20.49	-7.05	4.64
11	-9.82	16.65	-6.74	0.01
12	-8.04	12.52	-7.41	-2.45
13	-11.41	6.87	-12.10	-9.12
14	-14.04	4.51	-11.85	-13.63
15	-14.54	0.02	-9.58	-20.54
16	-14.66	- 7.26	-8.76	-30.53
17	15.66	-17.23	0.59	-30.85
18	-5.83	-19.70	0.00	0.00
19	0.00	0.00	2.82	-30.73
20	4.13	-20.13	10.63	-30.24
21	11.18	-19.55	11.05	-0.04
22	10.61	-0.03		

TABLE 6(vii)

Two-dimensional co-ordinates for plotting a skin pattern.
Co-ordinates in cm.

SIZE 14				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	11.31	0.00	11.05	0.00
3	11.35	9.95	10.05	13.29
4	11.48	18.67	6.95	12.87
5	6.49	21.19	3.04	14.98
6	4.69	26.24	-2.29	12.42
7	-0.82	24.25	0.00	0.00
8	0.00	2.50	-3.61	12.25
9	-5.00	23.83	-9.65	8.73
10	-11.11	20.49	-7.40	4.12
11	-9.17	16.15	-7.33	0.02
12	-8.28	12.26	-7.41	-2.45
13	-11.41	6.87	-12.17	-10.39
14	-14.46	3.29	-12.17	-10.39
15	-14.46	3.29	-12.17	-10.39
16	-14.45	3.29	-9.72	-30.53
17	-16.75	-17.24	0.52	-30.85
18	-5.42	-19.70	0.00	0.00
19	-0.10	-2.50	2.82	-30.73
20	3.22	-20.29	10.63	-30.24
21	11.18	-19.55	11.05	-0.04
22	11.31	-0.03		

TABLE 6(viii)

Two-dimensional co-ordinates for plotting a block pattern.
Co-ordinates in cm.

SIZE 16				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Bust prominence point	11.00	44.00	27.50
2	Between bust prominence	0.00	44.00	26.00
3	Mid front point	0.00	53.50	21.00
4	Neck point	0.00	60.00	17.00
5	Mid neck point	4.00	61.00	15.40
6	Shoulder/neck point	6.00	65.70	12.00
7	Mid shoulder point	11.50	63.20	12.00
8	End of shoulder	18.00	61.00	12.00
9	Mid upper armhole point	18.00	57.00	14.00
10	Mid armhole point	18.00	53.00	17.00
11	Mid lower armhole	17.00	49.00	17.00
12	Underarm point	19.00	45.00	14.00
13	Bustline point	18.50	44.00	14.00
14	Dart point on sideseam	16.50	35.20	14.00
15	Waist-side point	13.50	24.50	14.00
16	Mid-waist point	7.80	24.50	21.00
17	Centre waist point	0.00	24.50	22.00

TABLE 7(i)

Three-dimensional co-ordinates of crucial shaping points.

Front panel.

Co-ordinates in cm.

SIZE 16				
Point No.	Point Description	Co-ordinate		
		X	Y	Z
1	Shoulder blade	11.50	51.00	3.00
2	Mid-back point	0.00	51.00	3.50
3	Cervical point	0.00	67.00	6.00
4	Mid-neck point	3.00	66.60	8.00
5	Shoulder/neck point	6.00	65.70	12.00
6	Mid-shoulder point	11.50	63.20	12.00
7	End of shoulder	18.00	61.00	12.00
8	Mid-upper armhole point	17.00	57.00	9.00
9	Mid armhole	17.00	51.00	8.00
10	Mid-lower armhole point	17.00	50.00	8.00
11	Underarm point	19.00	45.00	14.00
12	Bustline point	18.50	44.00	14.00
13	Dart point at sideseam	16.50	35.20	14.00
14	Waist-side point	13.50	24.50	14.00
15	Mid-waist point	7.50	24.50	9.00
16	Centre waist point	0.00	24.50	7.50

TABLE 7(ii)

Three-dimensional co-ordinates of crucial shaping points

Back panel.

Co-ordinates in cm.

SIZE 16				
Point No.	FRONT	BACK		
	Linear Distance	Linear Distance	Curvature Factor	Curved Distance
1	-	-	-	-
2	11.10	11.51	1.00	11.51
3	15.92	19.93	1.00	19.93
4	22.07	18.46	1.00	18.46
5	22.01	18.09	1.00	18.09
6	27.13	15.16	1.00	15.16
7	24.68	14.94	1.00	14.94
8	24.05	10.11	1.00	10.11
9	20.01	7.43	1.00	7.43
10	15.50	7.50	1.00	7.50
11	13.09	14.60	1.00	14.60
12	15.72	14.80	1.00	14.80
13	15.44	19.89	1.00	19.89
14	17.03	28.76	1.00	28.76
15	23.85	27.46	1.00	27.46
16	20.80	29.24	1.00	29.24
17	23.05			

TABLE 7 (iii)

Linear and curved distances between apex point and crucial shaping points.

Distances expressed in cm.

SIZE 16					
Front			Back		
Point No.	Distance	Angle	Point No.	Distance	Angle
2 - 3	10.74	0.74	2 - 3	16.19	0.95
3 - 4	7.63	0.24	3 - 4	3.63	0.17
4 - 5	4.42	0.20	4 - 5	5.08	0.28
5 - 6	7.06*	0.20	5 - 6	6.04	0.32
6 - 7	6.04	0.21	6 - 7	6.86	0.46
7 - 8	6.86	0.28	7 - 8	5.10	0.13
8 - 9	4.47	0.09	8 - 9	6.08	0.64
9 - 10	5.00	0.12	9 - 10	1.00	0.13
10 - 11	4.12	0.24	10 - 11	8.06	0.37
11 - 12	5.39	0.33	11 - 12	1.12	0.07
12 - 13	1.12	0.07	12 - 13	9.02	0.44
13 - 14	9.02	0.55	13 - 14	11.11	0.28
14 - 15	11.11	0.44	14 - 15	10.00**	0.36
15 - 16	11.00***	0.48	15 - 16	7.65	0.26
16 - 17	7.86	0.35	16 - 2	26.80	1.16
17 - 2	19.91	1.04			
Upper part		0.42	Upper part		0.19
Lower part		0.28	Lower part		0.07
Full dart (ϵ)		0.70	Full dart (ϵ)		0.26

TABLE 7(iv), (v) and (vi)

Distances and angles between crucial shaping points and angle of dart.

Distances in cm. Angles in radians.

* including factor of 1.15 for body curvature

** including factor of 1.280 for body curvature

*** including factor of 1.29 for body curvature

SIZE 16				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	11.10	0.00	11.51	0.00
3	11.78	10.71	11.62	16.19
4	12.30	18.33	8.02	16.62
5	8.37	20.36	3.08	17.83
6	5.16	26.64	-2.25	14.99
7	-0.56	24.67	0.00	0.00
8	0.00	0.00	-4.99	14.32
9	-10.60	22.29	-10.67	10.46
10	-15.95	18.00	-8.10	6.06
11	-14.53	13.76	-7.43	0.00
12	-11.78	9.20	-7.43	-0.99
13	-12.05	5.09	-12.83	-6.98
14	-15.68	1.12	-12.43	-8.03
15	-15.44	0.02	-10.56	-16.86
16	-14.49	-8.95	-7.92	-27.65
17	-13.04	-19.97	2.16	-27.38
18	-2.07	-20.70	0.00	0.00
19	0.00	0.00	3.96	-27.18
20	3.73	-20.46	11.60	-26.84
21	11.58	-19.94	11.51	-0.04
22	11.10	-0.04		

TABLE 7(vii)

Two dimensional co-ordinates for plotting a skin pattern.

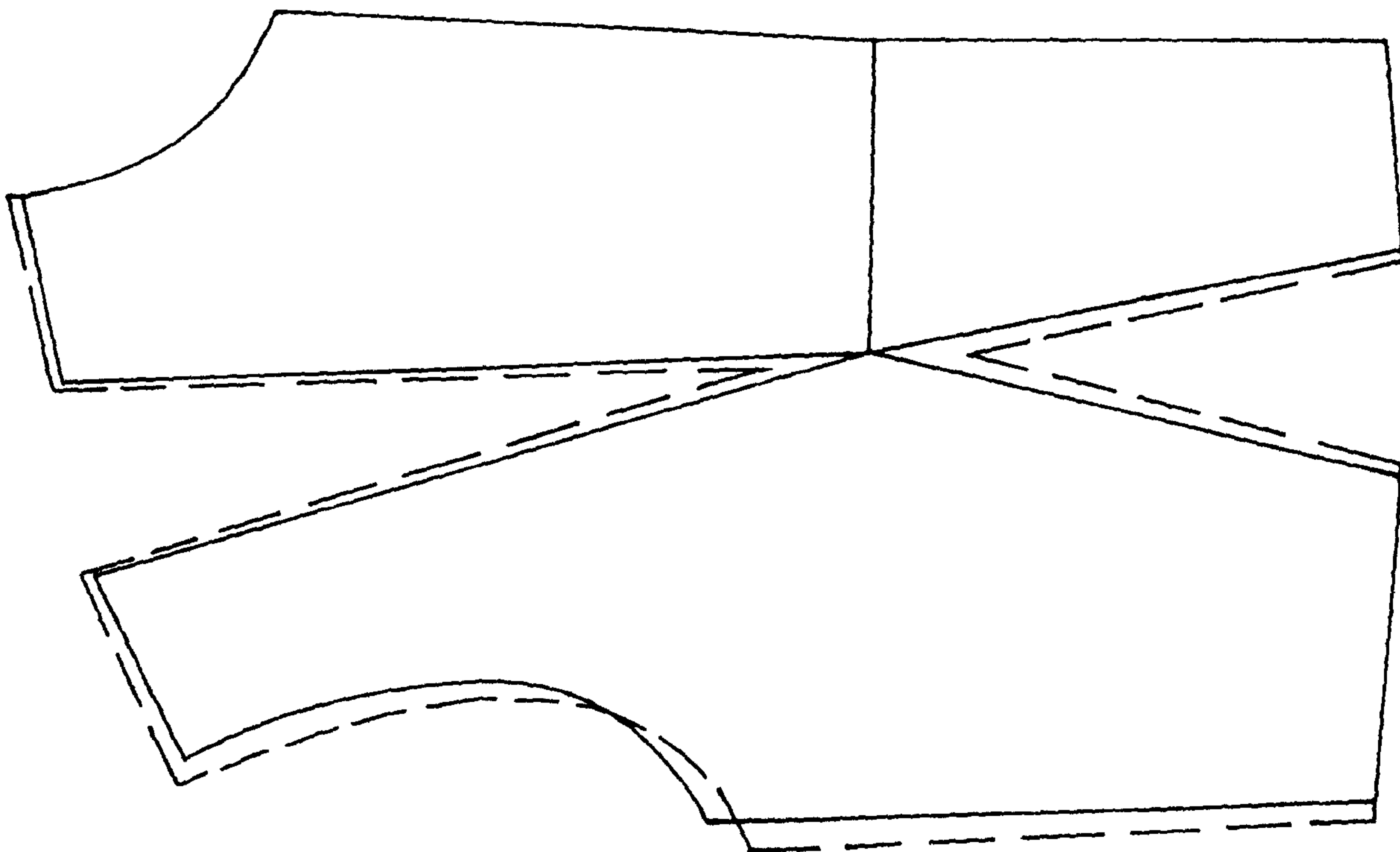
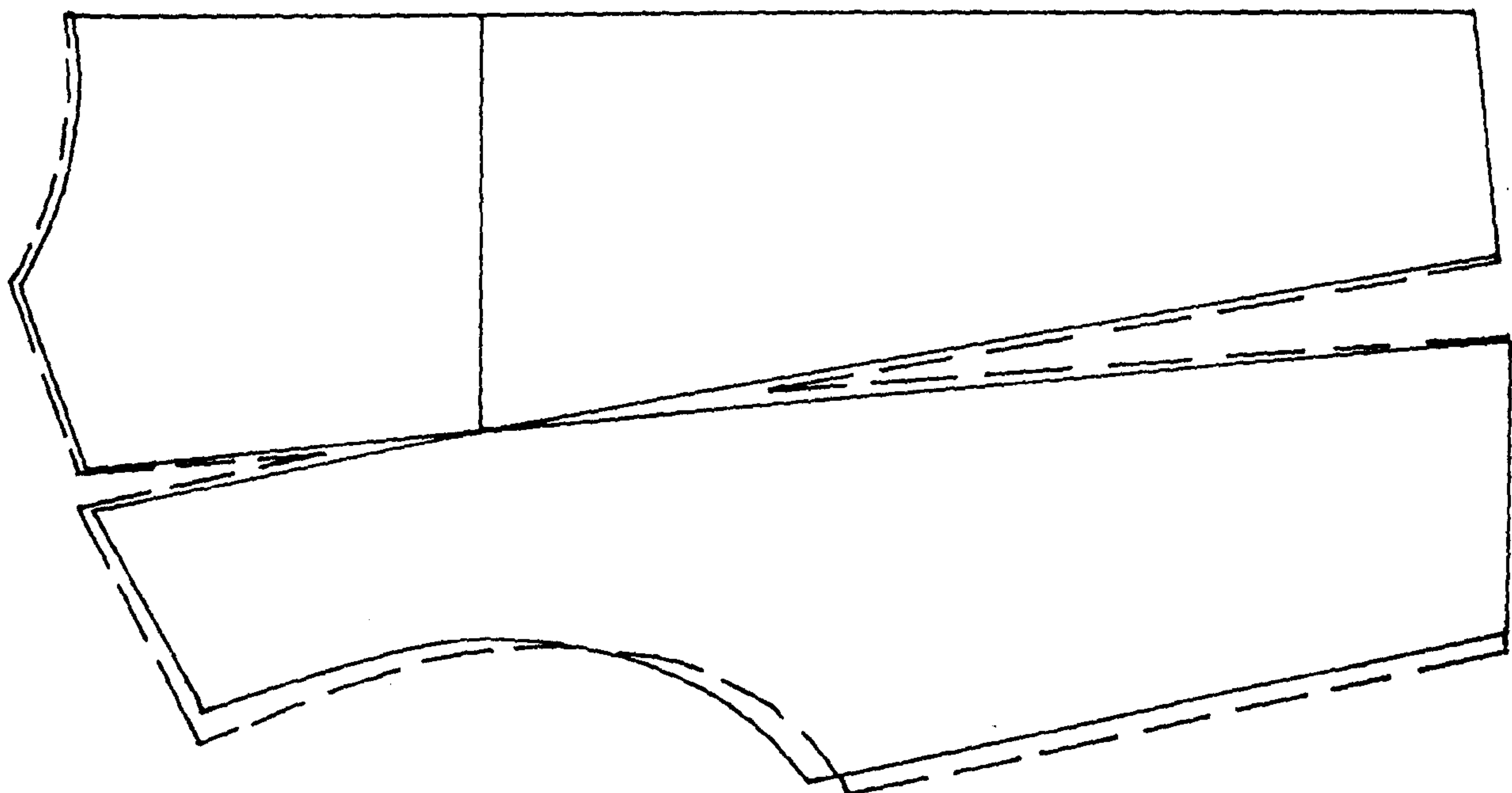
Co-ordinates in cm.

SIZE 16				
Point No.	Front Co-ordinate		Back Co-ordinate	
	X	Y	X	Y
1	0.00	0.00	0.00	0.00
2	11.80	0.00	11.51	0.00
3	12.16	10.71	11.62	16.61
4	12.30	18.33	8.02	16.95
5	8.37	20.36	3.08	18.18
6	5.16	26.87	-2.32	15.58
7	-0.62	25.04	0.00	0.00
8	-0.60	2.50	-5.23	14.74
9	-10.74	22.60	-11.31	10.46
10	-16.58	18.00	-8.50	5.39
11	-14.59	13.34	-7.43	0.01
12	-12.13	9.01	-7.43	-0.99
13	-12.05	5.09	-13.56	-7.95
14	-16.24	0.81	-13.56	-7.95
15	-16.24	0.81	-13.56	-7.95
16	-16.24	0.81	-8.67	-27.65
17	-13.53	-19.98	2.36	-27.38
18	0.00	-20.70	0.00	0.00
19	0.00	-2.50	3.68	-27.18
20	3.20	-20.62	11.60	-26.84
21	11.58	-19.94	11.51	-0.04
22	11.80	-0.04		

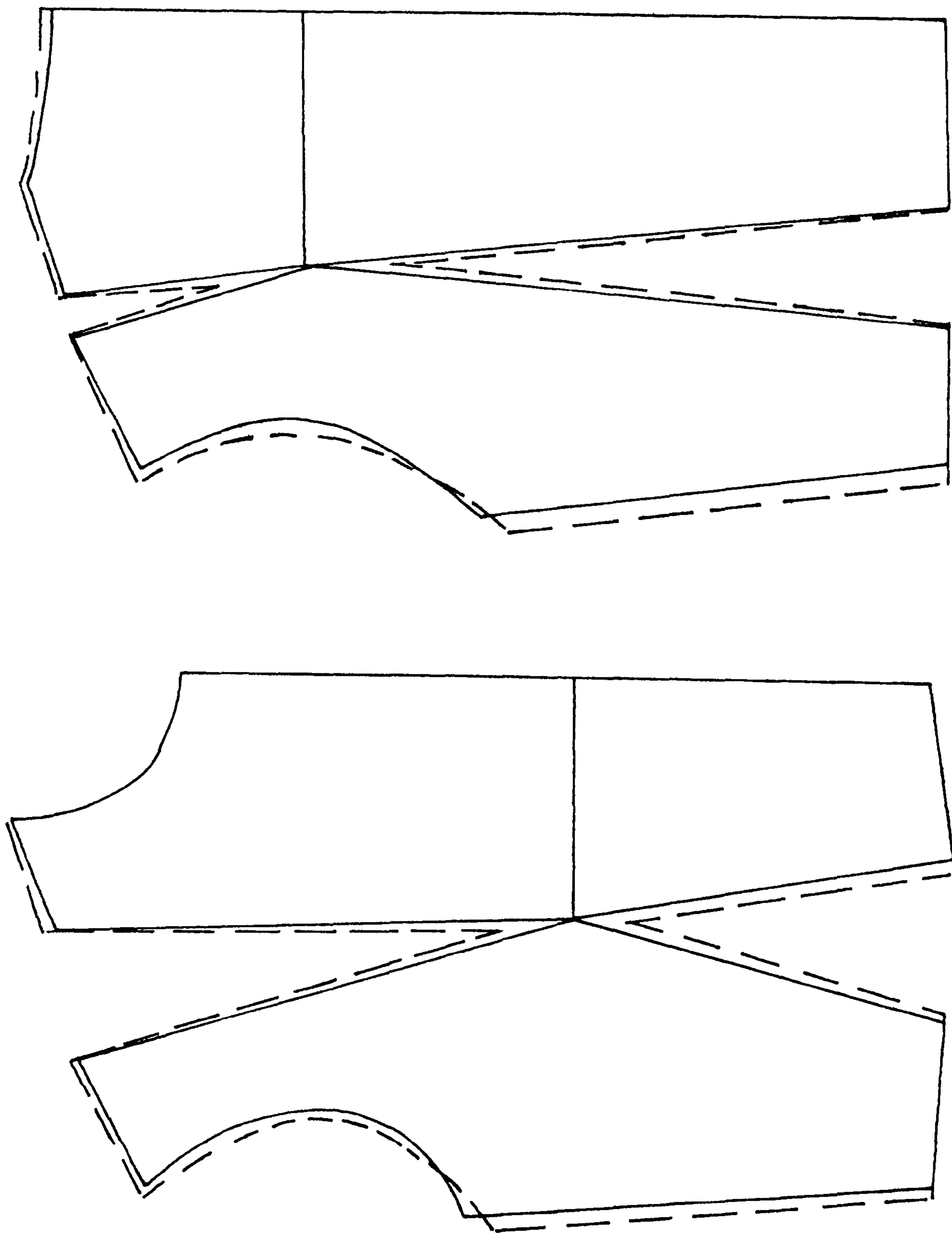
TABLE 7(viii)

Two dimensional co-ordinates of plotting a block pattern.

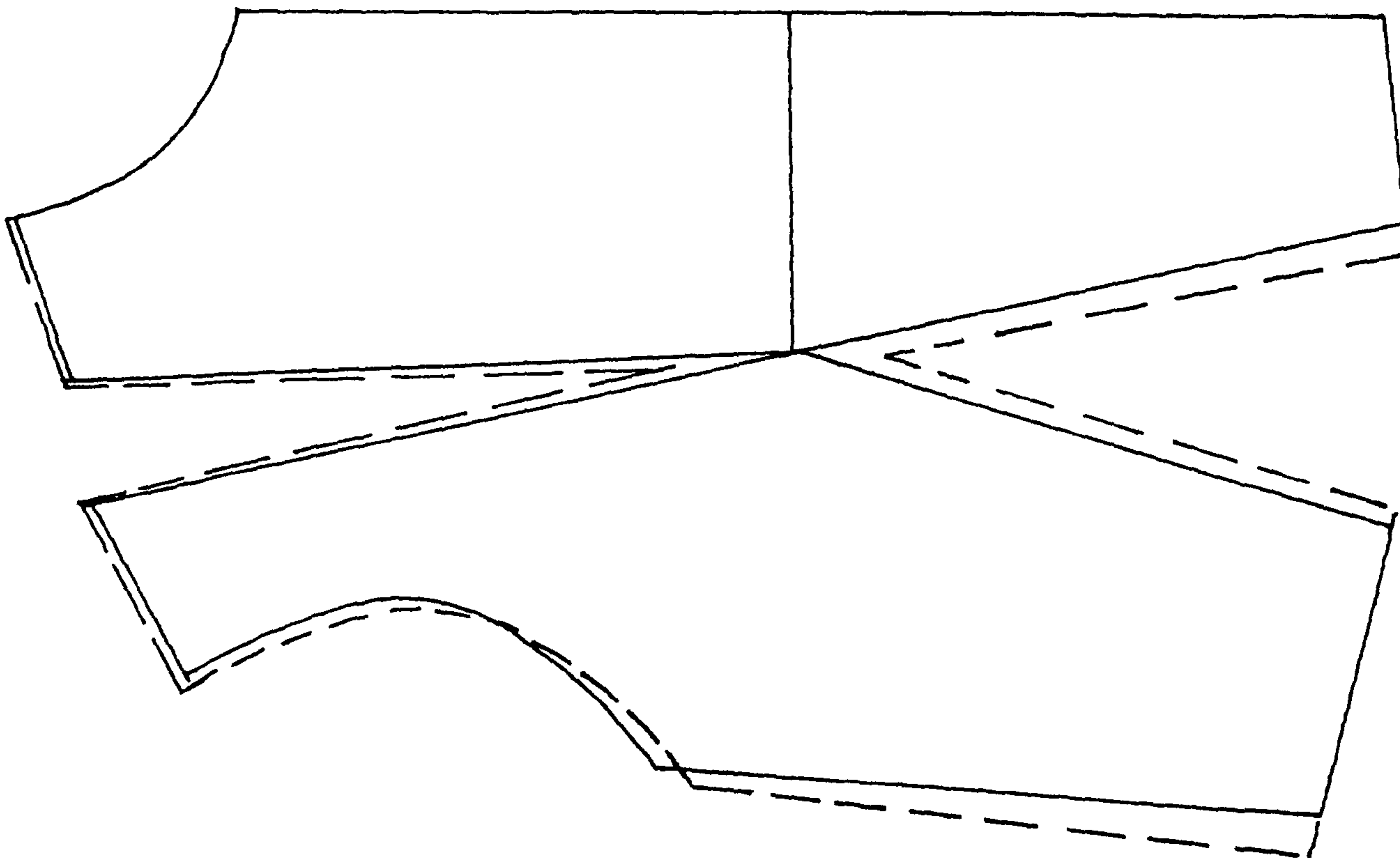
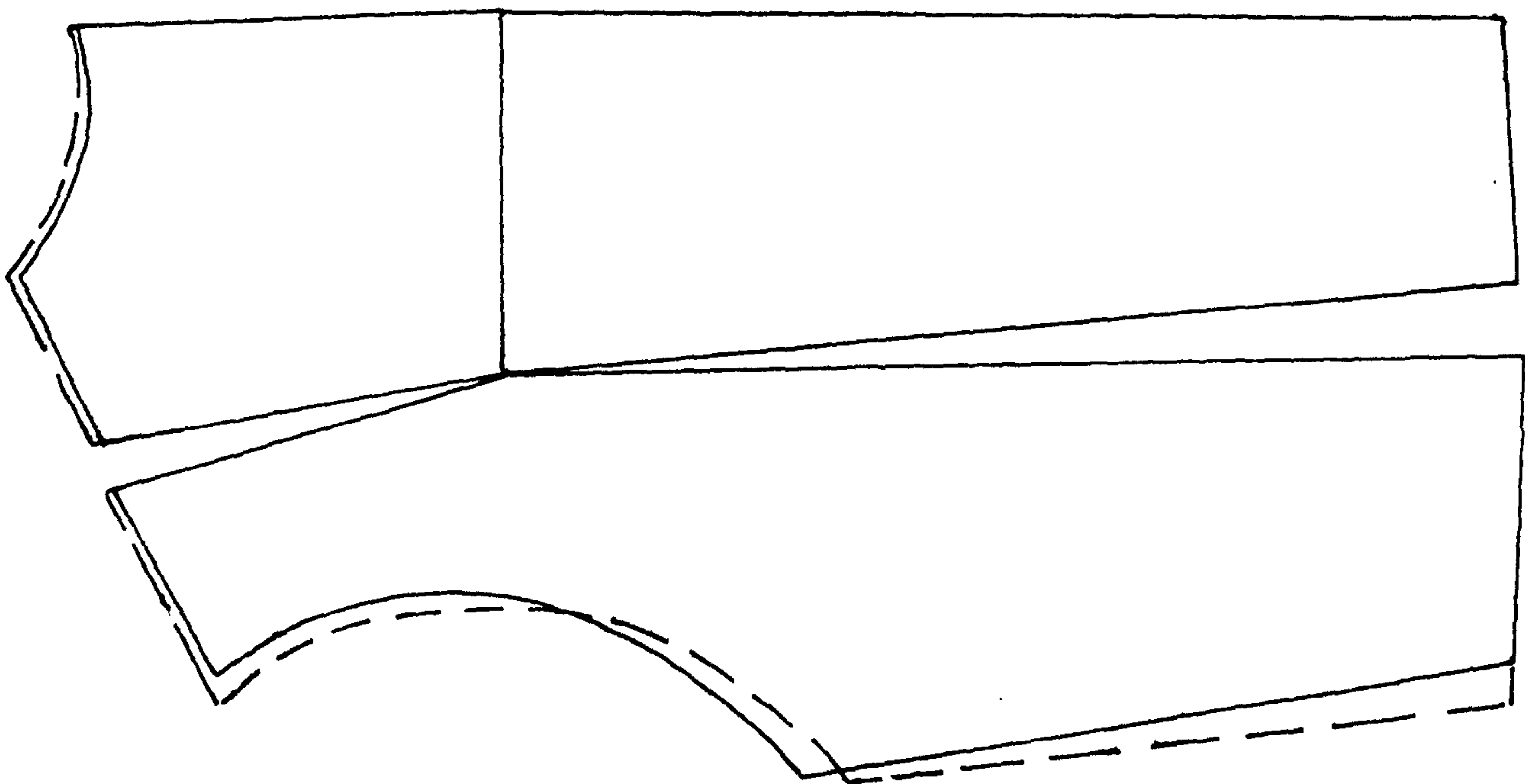
Co-ordinates in cm.



SKIN AND BLOCK PATTERNS SIZE 10

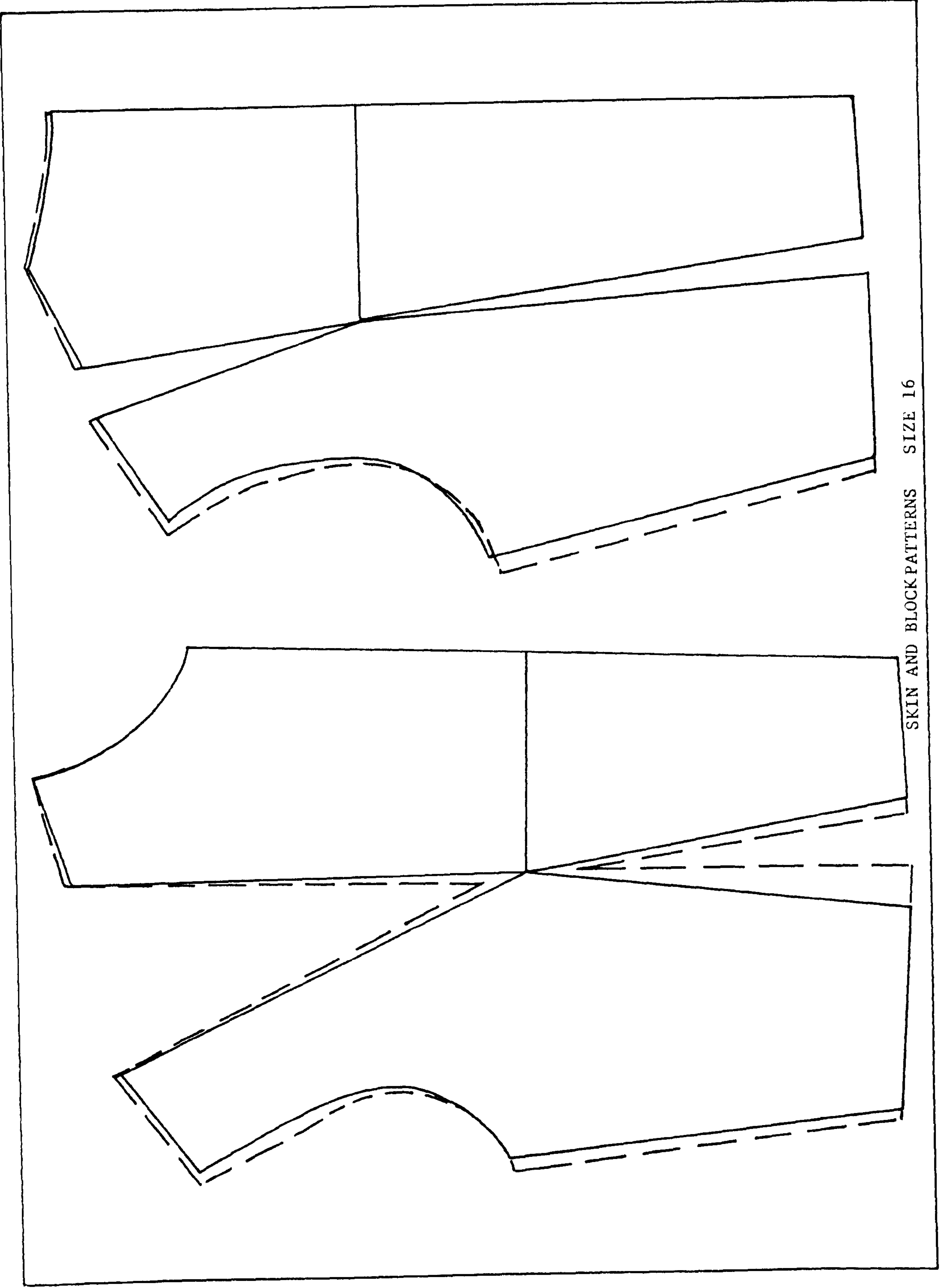


SKIN AND BLOCK PATTERNS SIZE 12



SKIN AND BLOCK PATTERNS SIZE 14

FIG. 45



SKIN AND BLOCK PATTERNS SIZE 16

FIG. 46

11.3 ANALYSIS OF THE RESULTS

11.3.1 General Comment

The information contained in tables four to seven is of considerable interest and value in describing the human body's anthropometry as well as posture, proportions etc., and there is no doubt that this information would be useful in these areas of study. However, since the aim of the work described in this thesis is to develop a system and method for pattern production which will achieve a better fitting garment, it is in this context that the results have been examined.

11.3.2 Comparison of apex angles measured on the stand with those calculated from angle of dart

As may be observed from the argument presented so far, the method of obtaining accurate skin and block patterns depends on achieving an accurate angle of dart which when inserted into the pattern will ensure a pattern which accurately fits the shape of the body measured; as shown in formula 6.3.8, the apex angle of each conical section of the body may be calculated from the dart angle.

To confirm if the angle calculated in this way was the same as the apex angle of the conical section measured on the stand, the following analysis was undertaken.

11.3.2.1 Front Panel

Fig. 47 shows a front panel with lines P-P1 and P-P2 drawn from the apex point (bust prominence) to mid-shoulder and mid-waist points respectively. It is clear that the angle that these two lines make at the apex point is an accurate description of the apex angle of the conical shape of the front panel.

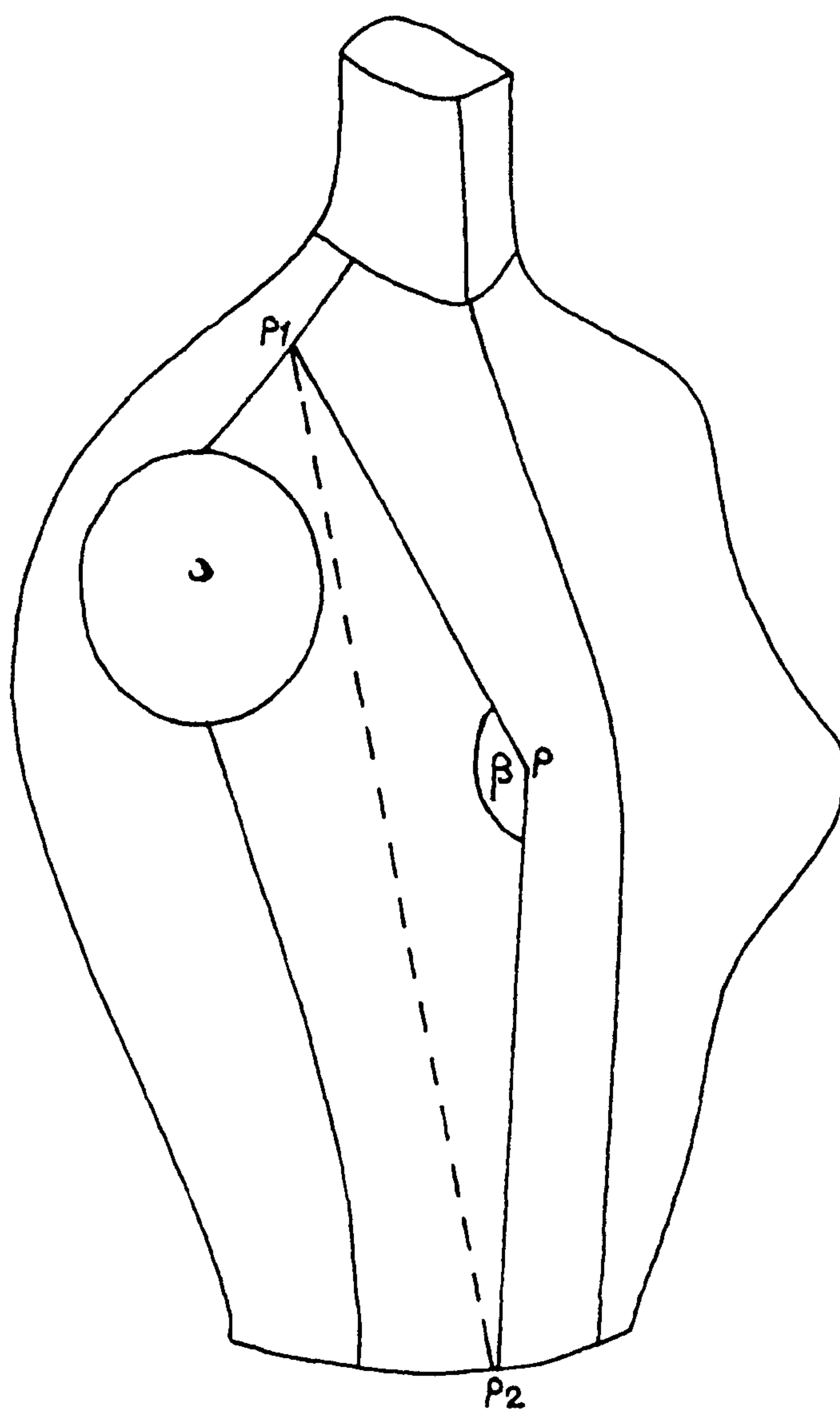


FIG. 47

If the co-ordinates of points P, P1 and P2 are known, then the apex angle of the front panel may be calculated from formula 7.2.

The results obtained for both measured and calculated half apex angles for each figure size are given in Table 8.

Front Panel			
Size	ϵ	α_T	α_E
10	37.3°	63.7°	64.3°
12	37.8°	63.5°	63.0°
14	37.8°	63.5°	62.0°
16	40.1°	62.6°	61.2°

TABLE 8

Measured and calculated apex angle

legend:

ϵ = angle of dart

α_T = apex angle calculated from angle of dart

α_E = apex angle calculated from stand co-ordinates

It is to be observed that in all figure sizes measured, the angles obtained from the two different methods are within 1.5° of each other. A remarkable indication of the accuracy of the method for producing patterns with the correct 'cone shape'.

11.3.2.2 Back Panel

Fig. 48 shows a back panel with lines B-B1 and B-B2 drawn from the apex point (shoulder blade) to mid-waist and mid-shoulder respectively.

As has been indicated earlier, the shape of a back panel differs from that of the front panel in that the upper part of the back panel (see line B-B2 , Fig. 48) is highly curved as it approaches the shoulder

area so that a line drawn from the shoulder blade point (B) to the mid-shoulder point (B2) will take the form of a convex shaped line.

Hence, the angle that the two lines make at the apex point (B) cannot be used to calculate the apex angle of that panel. Since the line from the apex point (B) to mid-waist point (B1) is reasonably straight, a more accurate way of assessing the apex angle is to consider that the angle (α) between the line B-B1 and the vertical line onto B1B2 is half the apex angle.

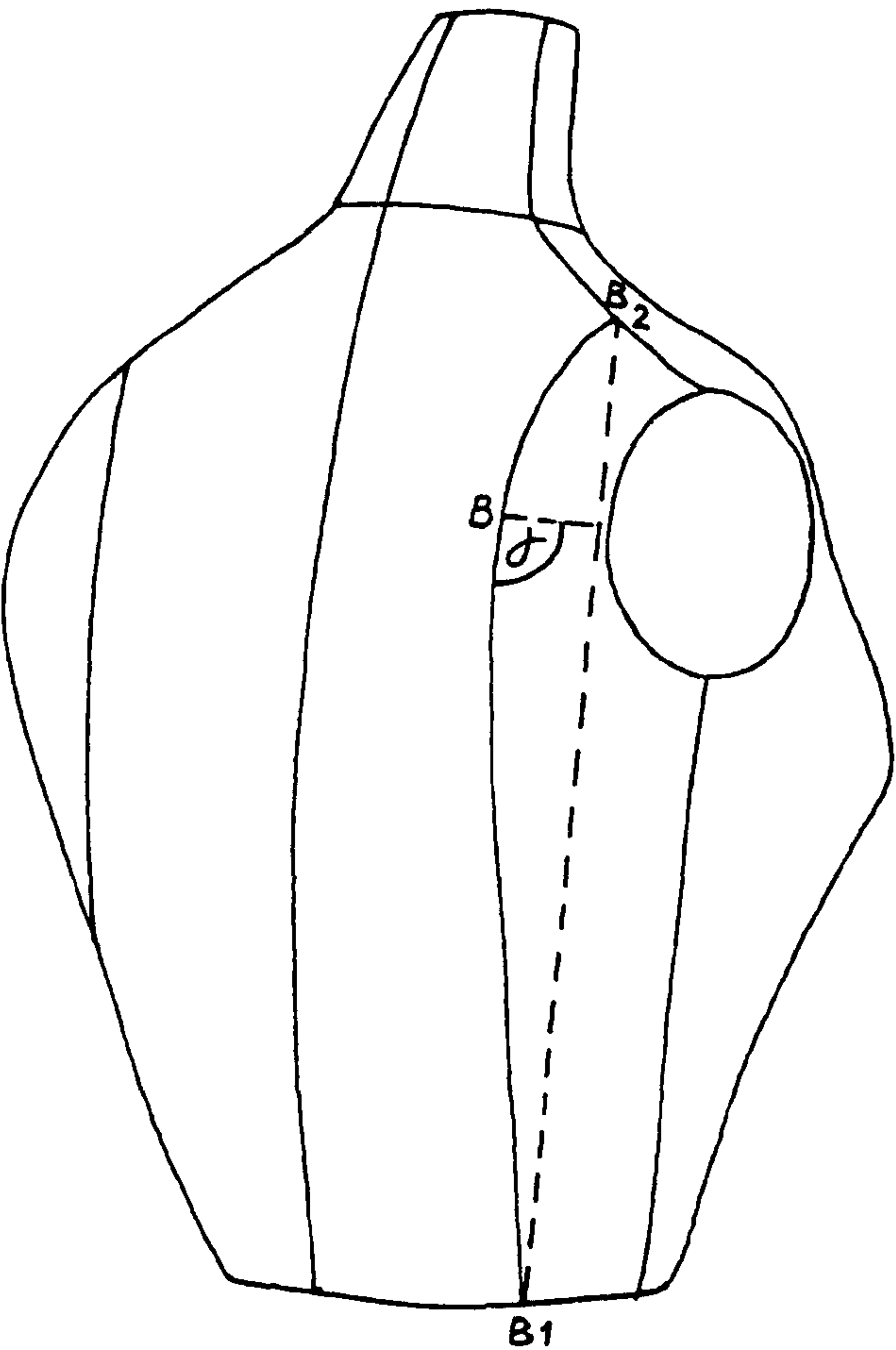


FIG. 48

The (α) angle calculated in this way is compared with that calculated from the formula 6.3.8 and both are given in table 9 overleaf.

Back Panel			
Size	ϵ	α_T	α_E
10	9.74°	76.63°	75.41°
12	13.75°	74.10°	76.6°
14	9.8°	76.63°	73.82°
16	14.9°	73.7°	72.76°

TABLE 9

Measured and calculated apex angle

Legend:

ϵ = angle of dart

α_T = apex angle calculated from angle of dart

α_E = apex angle calculated from stand co-ordinates

The agreement between the values is within 2.8° , again showing the extremely good agreement between the two methods of assessment.

11.4 FIT ASSESSMENT

11.4.1 Assessment Procedure

Although the above analysis indicates a very good agreement between the pattern design and the three-dimensional co-ordinates of the body figure, the ultimate assessment of the patterns produced by the computer program is to determine physically and subjectively the fit on the figure for which they were produced.

In this assessment, sample garments based on the full size skin patterns obtained by the computer program, were cut and made up for each size measured. To ensure the most crucial condition for fit, the garments were made from a rigid cotton calico, which is exceptional in that it combines great rigidity* with minimum thickness, so that:

- (a) the skin fit sample garment could be used without any allowances for the thickness of the fabric.
- (b) in the case of inaccuracy in the fit of the garment, the fabric would not overcome such inaccuracies by stretching to the shape of the figure measured. (i.e. this type of fabric will ensure that if accurate fit is achieved, it is because of the accuracy of the patterns from which the garment was made rather than garment accommodating to the stand by fabric distortion).

* On test, the fabric was found to stretch by less than 5% for an applied load of 3kgs. per 3 inchsquare of fabric.

11.4.2 Details of Assessment Results

It will be appreciated that for these sample garments to fit the figures accurately

- (i) the garments should fit the figures smoothly and accurately
- (ii) the sample garment's seam should follow the natural line of the figure.
- (iii) the garments should fit the figures like a second skin.

After the garments had been made up they were put on the appropriate stands. It was immediately clear that no accurate assessment of the fit of the garment was possible because of the separation of the two front panels. This was overcome by inserting a zip so as to permit the front panels to be joined together along the centre front.

The garments were then again, placed on the appropriate stand and the front pieces were zipped together (see Figs. 49 - 54).

Figures 49, 50 and 51 show the front, back and side views of size 12 and Figures 52, 53 and 54 show one view of each of the other three sizes measured.

It is to be observed that:

- (i) the garments correspond accurately to the shape of the stands they were designed for.
- (ii) the seams (i.e. side-seam, shoulder seam) and lines (i.e. waistline, neck line, etc.) accurately follow these lines on the stands.

- (iii) no wrinkles (which are an indication of poor fit) are to be detected, and if a wrinkle is to be seen, it is due to poor making up.
- (iv) the darts of each panel are tapering to the exact location they were designed for.
- (v) the garments fit the figures like a second skin.

In order to further confirm the quality of fit of these garments, a sample garment was made up from a pattern constructed by a traditional method, where slight modifications were made so as to achieve a garment of unsatisfactory fit. When hung on a stand (see Fig. 55) it was obvious that:

- (i) the shoulder and side-seam of the garment did not follow the stands natural line.
- (ii) the length of the shoulder seam is shorter than this required to cover the length of the shoulder on the stand.
- (iii) surplus fabric is evident on all areas of the body.

After assessing the quality of fit of these garments, it was considered desirable to submit the sample garments to an objective fit assessment test, which was carried out by three garment design experts, who were asked to give their assessment of the quality of fit of these garments. Their comments are given in Appendix 4, but may be summarised as follows:

- (i) Size 10 - generally a good fit.

Criticism - has slightly surplus fabric at cross back level.

(ii) Size 12 - generally a very good fit.

Criticism - dart poking at shoulder blade level.

(iii) Size 14 - generally a very good fit.

Criticism - slightly wide at across back level.

(iv) Size 16 - generally a very good fit.

Criticism - slightly wide at across back and has slightly surplus fabric at cross chest level of armhole area.

General Comments:

(i) waist level fitting of all sizes very good.

(ii) neck line level of all sizes very good fitting.

(iii) armhole shapes not satisfactory.



FIG. 49

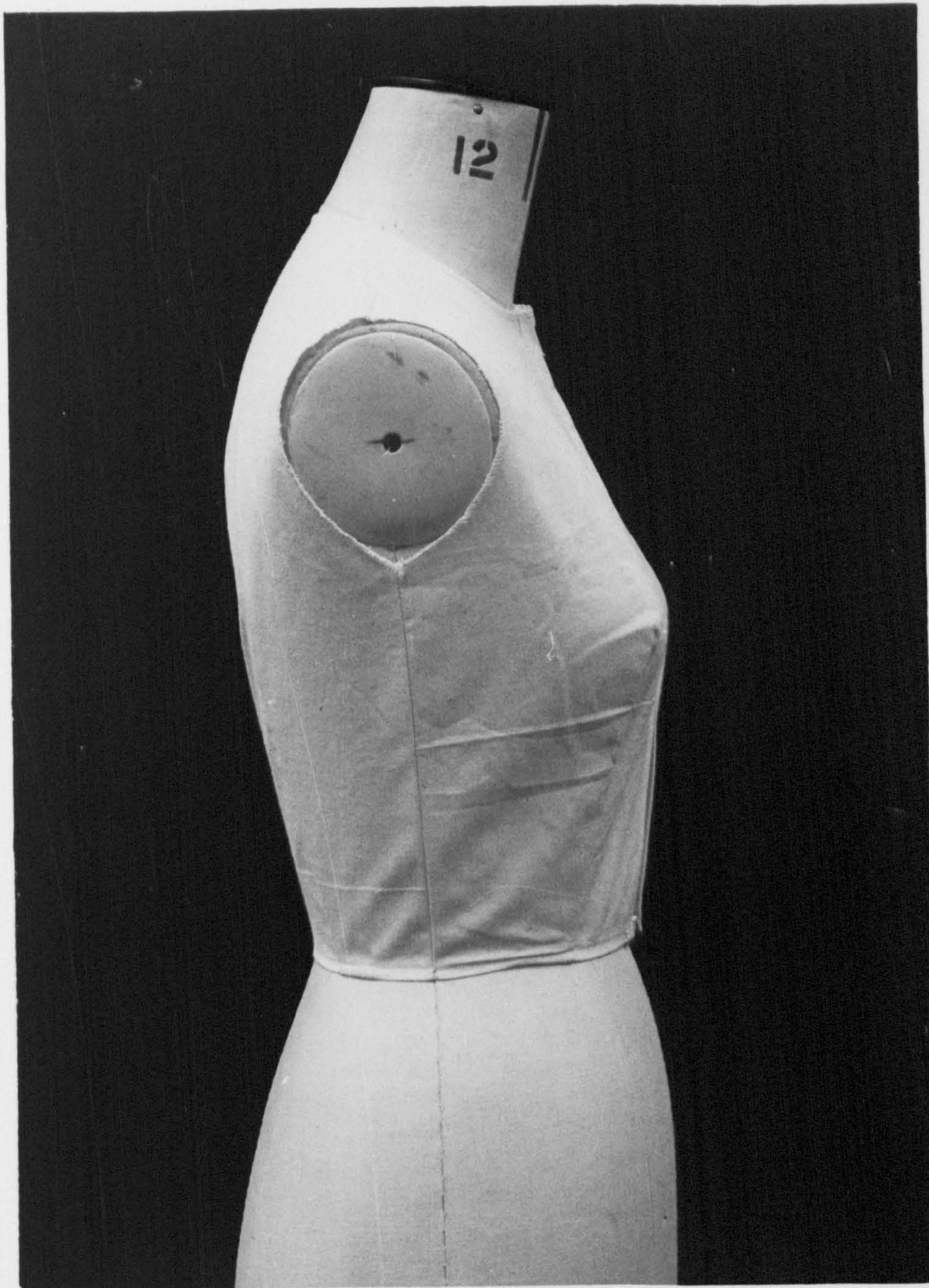


FIG. 50

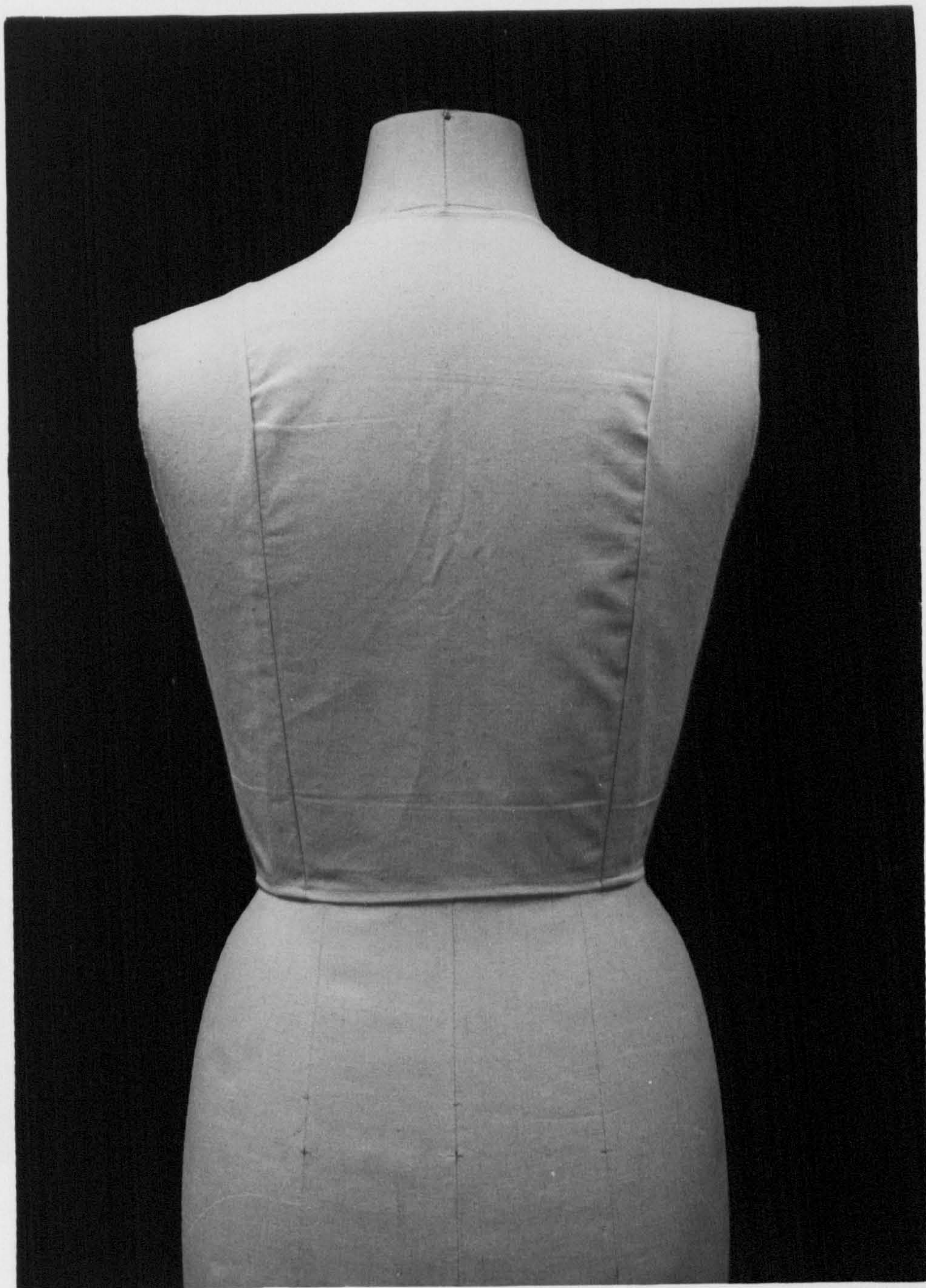


FIG. 51

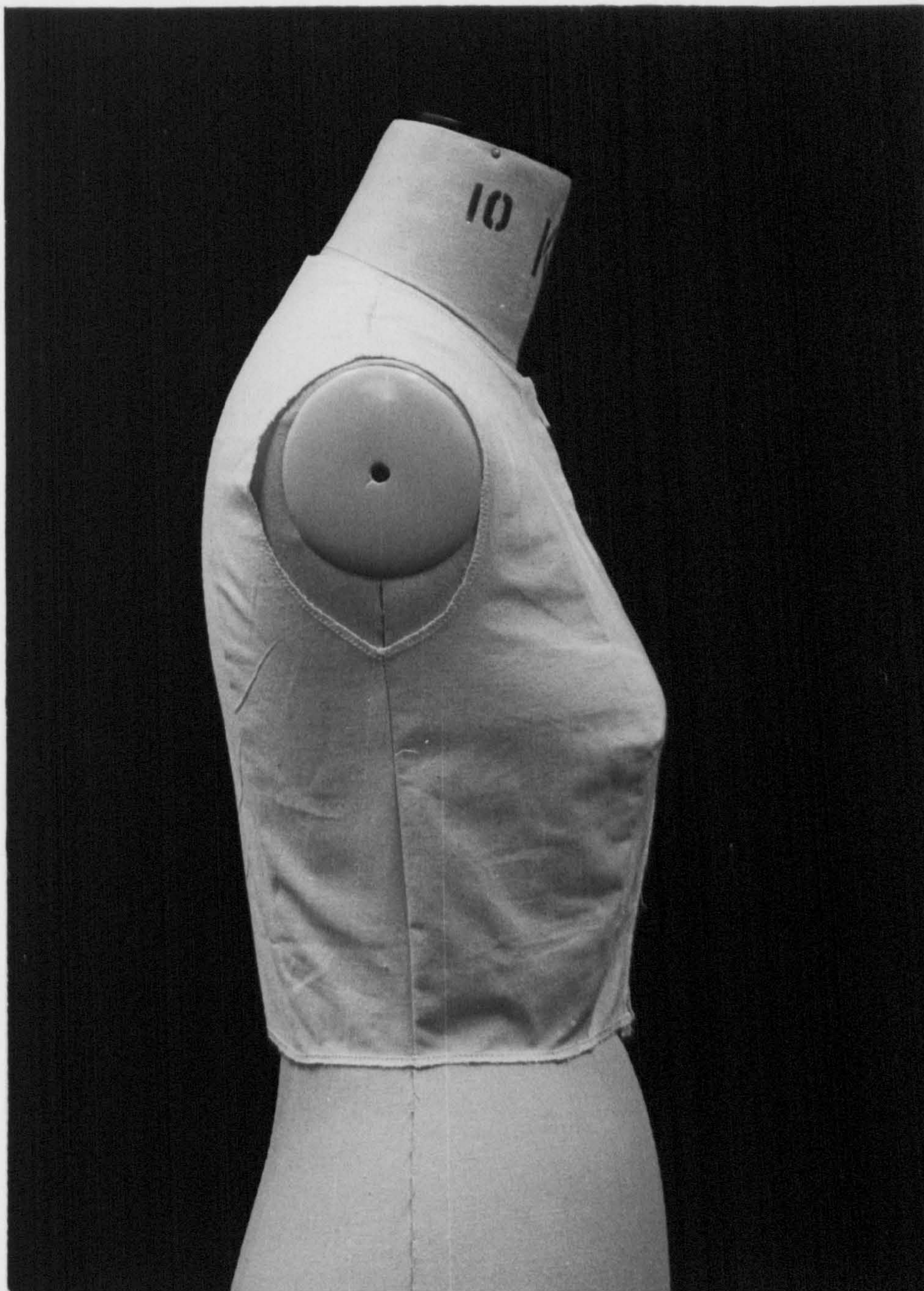


FIG. 52



FIG.53

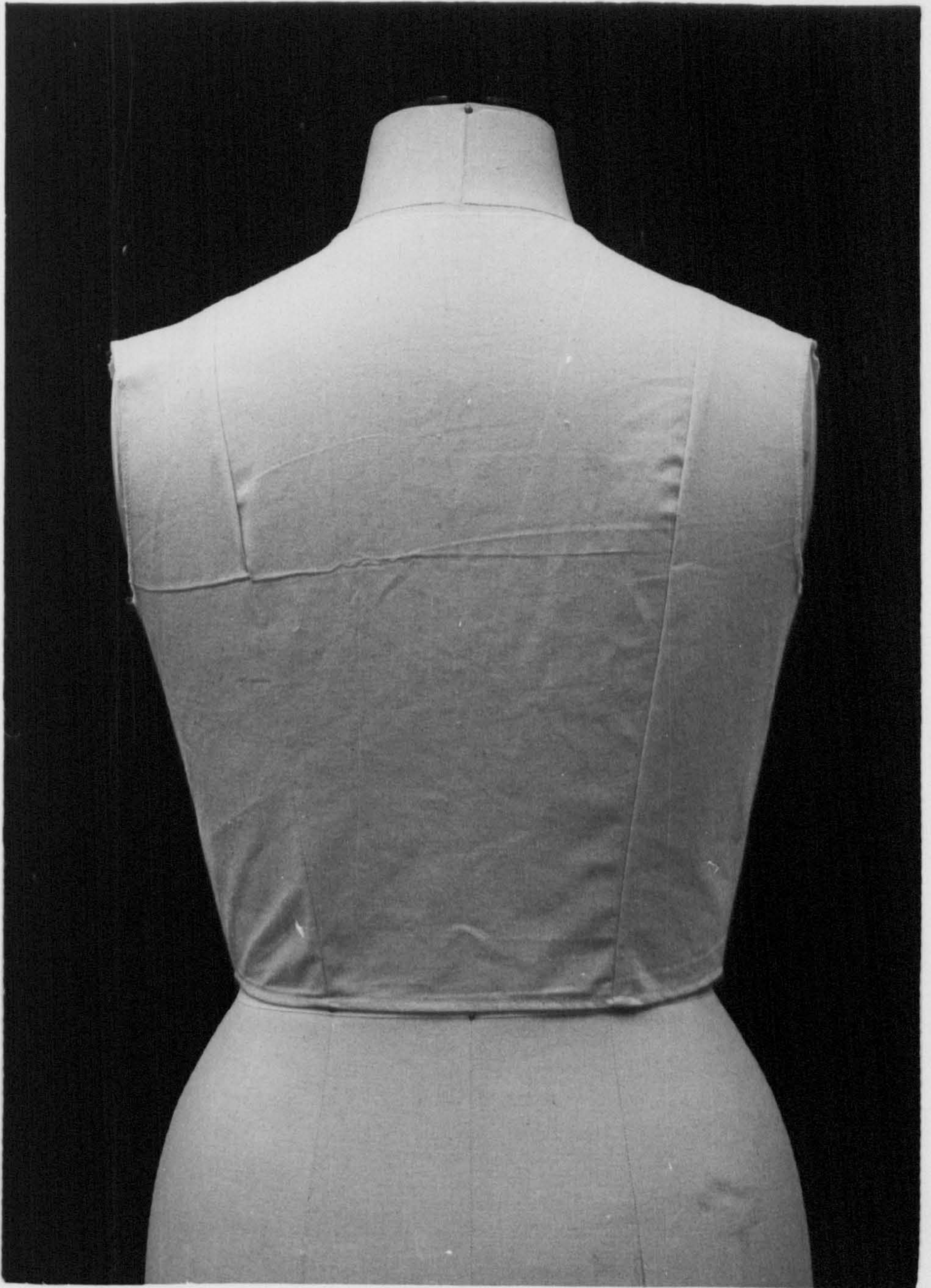


FIG. 54



FIG. 55

11.5 CONCLUSION

It was evident from the results obtained that the method of obtaining a garment of good fit from measurements of the three-dimensional co-ordinates of the body on which the garment was required to fit, was a very satisfactory technique and that the derived computer program was accurate and perfectly suited for this purpose.

CHAPTER TWELVE

COMMERCIAL APPLICATIONS

12.1 INTRODUCTION

Since the computer system developed in this thesis was intended to be used as a tool to produce patterns which will ensure a garment of better fit, it is interesting to consider the ways in which this technique might conveniently be applied to the commercial world.

The four areas of application may be identified as follows:

- (a) Side-street bespoke tailor. The computer program is sufficiently simple to make it realistic that even the smallest of tailors would be able to cut his garments by the new method, employing a small table model computer.
- (b) High-street bespoke tailor. The 'high street' package will comprise a powerful computer that will be used to produce patterns for ready-to-wear garments in many different styles and the full range of sizes. The patterns may be paper patterns or may simply be electronic instructions to cutting-out machinery.

The latter is today being increasingly controlled by computer techniques; however, the information fed to the computer, the shapes of patterns and so on, are obtained from traditional methods and hence, computer cutting delivers the same end product as far as fit is concerned, as that obtained by conventional methods.

The method described in this thesis would allow not only automation of the process, but also improved performance because of the more accurate fit that would result.

- (c) Ready-to-wear. Survey of measurements of people giving average and range of measurements would lead to a much more realistic range of garment sizes being offered to customers, together with required numbers of each size, for age group, height, etc.
- (d) Patterns for home dressmaking. Instead of purchasing a pattern and adjusting it to the individual body, the computer would provide the accurate pattern shapes necessary for any customer to any style, from co-ordinate point measurements of the individual customer.

12.2 COMMERCIAL METHOD FOR MEASURING THE THREE-DIMENSIONAL CO-ORDINATES OF THE HUMAN BODY

It is obvious that since inaccuracies when measuring a human would arise as a result of the person not being able to remain still throughout the measurement process, in order for any of these applications to become commercially viable, a more speedy measuring device was called for.

A detailed survey of various methods, techniques and devices was carried out, as a result of which the apparatus and method described below was discovered, which seemed to offer all the required features to measure the human body with speed and accuracy. Unfortunately, the apparatus was not available for use during the course of the work described in this thesis so that the practical application of the method could not be assessed

The apparatus, which was originally developed to record human movements in patients suffering from movement disorders, was a remote and non-contacting means of monitoring and recording the position of selected target points on the human body (49). It consists of three major components:

- (i) the subject worn landmark system.
- (ii) a set of electronic cameras
- (iii) a signal processing unit for transmitting signals generated in the cameras to voltage analogues of the three-dimensional cartesian X, Y and Z co-ordinates of each point selected on the body.

The general layout of subject, landmarks, cameras and processing unit are illustrated in Fig. 56.

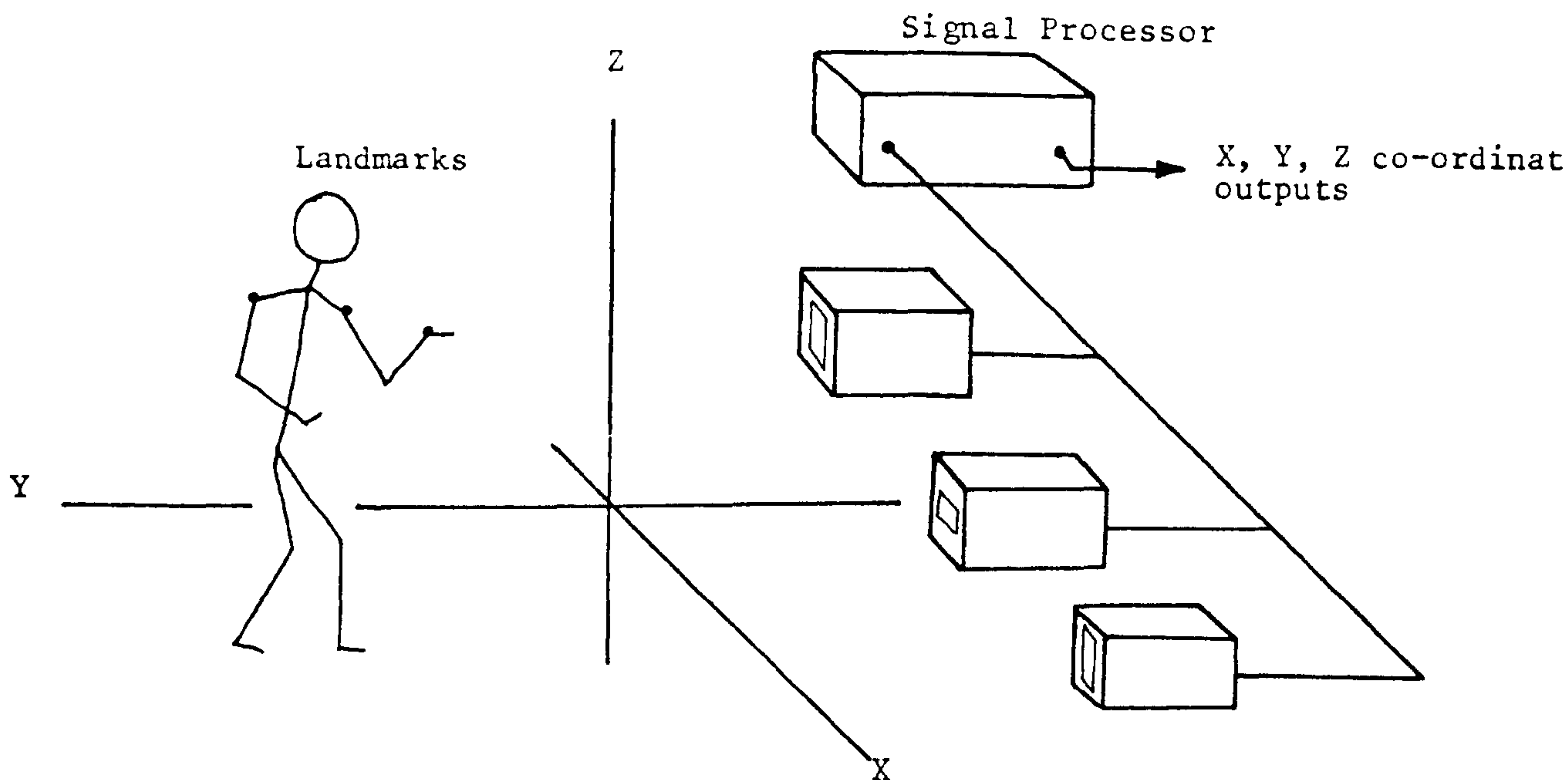


FIG. 56

The landmarks are high power infra-red units which emit lights to the electronic cameras. These cameras and the signal processing unit are shown in Fig. 57. The two outside cameras are sensitive to horizontal movement of the landmark in the X dimension and since these two cameras are separated by a known distance, it is possible to use their output signal to determine stereoscopically, the position of the landmark in the Y dimension. The third camera, which is sensitive to vertical movement only, is centered between these two cameras and provides the Z dimension co-ordinate of the landmark. The computation of the three-dimensional cartesian co-ordinates of each of the points measured takes less than 90 micro-seconds.

Recently, an improved version of the above apparatus has been designed, which is based on the same principle but uses a beam of light to replace the electronic cameras and a prism landmark to replace the high powered infra-red light landmark system. On examination and demonstration of the improved apparatus, it was evident to the author of this work that the accurate measuring of the three-dimensional

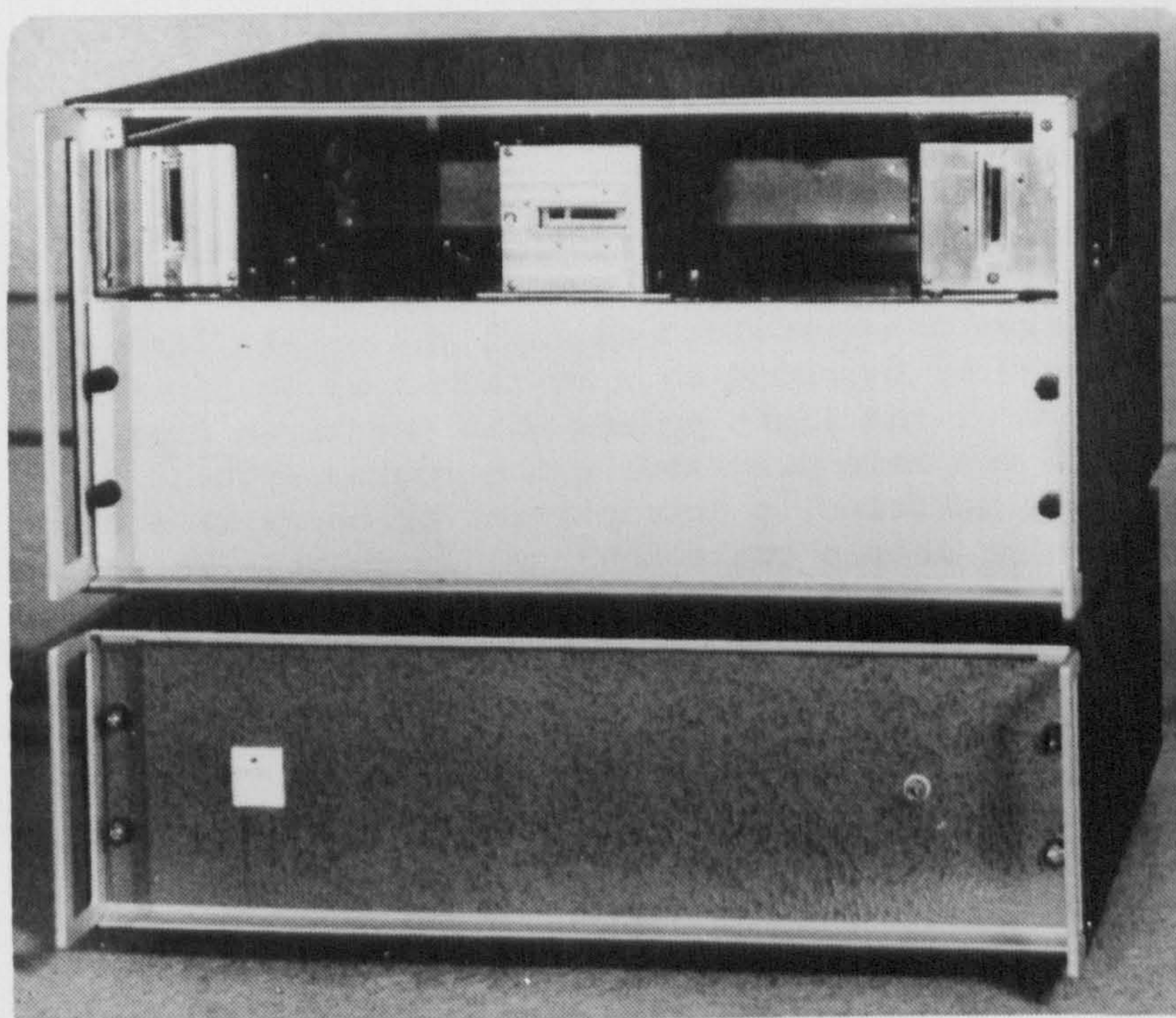


FIG. 57

co-ordinates of the crucial shaping points on the human body described in this thesis, was well within the capabilities of this apparatus, and if used in conjunction with the work described in this thesis, it would ensure a speedy and accurate method of obtaining the three-dimensional body co-ordinates. It was estimated that the time needed to take the co-ordinates of a complete set of crucial shaping points would be of the order of 1 - 2 seconds.

One of the most important and outstanding advantages of the improved apparatus is that the landmarks are passive devices requiring no power or wires on the subject. They are small and can be rapidly and conveniently fixed to the designated points on the subject, and may remain visible when tilted throughout a total range of 220 degrees solid angle.

Another important advantage of this improved device in so far as the work described in this thesis is concerned, is the fact that since the computations are carried out by a computer, it is possible to use this computer to run the program developed in this thesis.

CHAPTER THIRTEEN

SUMMARY AND CONCLUSIONS

13.1 INTRODUCTION

The account given in this thesis is the result of an experimental and theoretical investigation into the ways in which garments made to fit the three-dimensional body, may be obtained from two dimensional fabric patterns.

The main areas of work described in this thesis may be itemised as follows:

1. Survey of present state of the art (Chapters 1, 2, 3 and 4).
2. Establishment of the relationship between the angle of dart and apex angle of a cone. (Chapters 5 and 6).
3. Study of the relationships between body and pattern shapes. (Chapters 7, 8 and 9).
4. Development of a computer program to produce patterns to fit the human body. (Chapter 10).
5. Assessment of accuracy of the patterns in producing garments of satisfactory fit. (Chapter 11).
6. Commercial applications. (Chapter 12).

The main content of these areas is detailed overleaf.

13.2 PRESENT STATE OF THE ART

Chapter 1 of this thesis consists of an introduction to the basic technology of pattern production and describes the different methods currently used for producing patterns. A survey of previous investigations into assessment of body shape and the ways body shape has been determined is described in Chapter 2. Hutchinson's and Whife's work are discussed in detail.

Chapter 3 describes the means by which three-dimensional body measurements may be obtained and Chapter 4 describes the way in which garment fit had been assessed and defined.

13.3 THE RELATIONSHIP BETWEEN ANGLE OF DART AND APEX ANGLE OF A CONE

In Chapter 5 and 6 consideration is given to the features involved in the conversion of a flat pattern into a three-dimensional garment. It is suggested that this is achieved primarily by the insertion of darts so that when a triangular section is cut from a circular two dimensional flat fabric, the resultant fabric when the two edges are joined together forms a three-dimensional right circular cone. A theoretical consideration reveals that the relationship between the angle of the cut section (ϵ), and the apex angle (α) of the cone is given by the following formula.

$$\cos \alpha = \sqrt{1 - \left(\frac{2\pi - \epsilon}{2\pi} \right)^2}$$

13.4 THE RELATIONSHIP BETWEEN BODY AND PATTERN SHAPES

In Chapter 7, an attempt is made to apply the above relationship to the bodice of the human figure.

Examination of the bodice panels reveals that each of these two panels (i.e. front and back) may be looked upon as individual sections of the body, which may effectively be represented by separate cones, which of course, are realised not to be right circular ones. By applying the cone principle to the front and back panels of the human figure, it is suggested that to achieve garments of satisfactory fit requires only the accurate determination of the apex angle of each of the body panels.

Since the measurement of this angle is not possible for practical purposes, further consideration revealed that another practical approach using the same principal, was to measure the three-dimensional co-ordinates of a number of crucial shaping points selected on the body which will be sufficient to define the shape of each body panel accurately.

Essentially this is achieved by dividing each of the body panels into a number of annular triangular sections radiating around its apex point, measuring the distance of each leg and calculating the angles of each triangular section. It is obvious that the summation of all these triangular sections will give the outline of the pattern shape and the sum of all the angles that each triangular section makes at the apex point will give the angle subtended by the fabric at the apex point. The way in which the two dimensional co-ordinates of each pattern are obtained is detailed in Chapter

Corrections were considered advisable in certain sections of the body where the actual shape between two crucial shaping points was curved rather than straight. To accommodate this, a factor method was used to increase the length between the crucial shaping points by the appropriate amount.

In order to measure the three-dimensional co-ordinates of the crucial shaping points selected on the body, a new measuring device was designed and developed, and it is this development and the practical use of it which is described in Chapters 8 and 9.

13.5 DEVELOPMENT OF A COMPUTER PROGRAM TO PRODUCE PATTERNS TO FIT THE HUMAN BODY

Although the number of the crucial shaping points selected on each panel is not large, the computation of the information needed to produce a skin and/or block pattern would have been tedious were it not for modern computing techniques. The advantage of these techniques has been taken in Chapter 10, where the appropriate computer program is described.

This program:

- (i) reads the three-dimensional co-ordinates measured on the body.
- (ii) calculates the distances and angles of each of the triangular sections.
- (iii) establishes the angle of dart needed to be inserted into the flat fabric.
- (iv) plots the full size skin and block patterns.

13.6 ASSESSMENT OF ACCURACY OF PATTERNS IN PRODUCING GARMENT OF SATISFACTORY FIT

In Chapter 11, the accuracy of the resultant patterns was assessed by:

- (i) comparing the apex angle obtained from the angle of dart of the pattern, with that obtained from the three-dimensional co-ordinate measured on the body.
- (ii) subjective and objective assessment of garments constructed from these patterns when hung on the measured body.

13.7 COMMERCIAL APPLICATIONS

In Chapter 12, an indication of possible commercial applications of the method are described, along with a description of a practical and rapid method for measuring the three-dimensional co-ordinates of the human body.

APPENDICES

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FILE 41(KIND = DISK,TITLE = "BASK")
FILE 42(KIND = DISK,TITLE = "FABL")
FILE 43(KIND = DISK,TITLE = "BABL")
      REAL X(41),Y(41),Z(41),DESC(4,41),SUBX(41),SUBY(41),SUBZ(41),D
IS
      - (41),LEN(3),Q(3),MEN(2),B(41),BA,D,ZAVIT(60,3),DESK(4,41)
      WRITE(1,10)
10  FORMAT("      WHAT YOU ARE ABOUT TO SEE IS A NEW APPROACH IN      "
/
      -,"                                                    " /,
      - "                                                    "
/,
      - "      PRDUCTION OF PATTERNS                        " ///,
      - "      THE FOLLOWING PROGRAM HAS BEEN DESIGNED TO ENABLE THE" /
//
      -,"                                                    " /,
      - "      USER TO USE 3D BODY MEASUREMENTS FOR THE      " ///,
      - "      PRODUCTION OF WELL SHAPED PATTERN PIECES      " //)
20  WRITE(1,30)
30  FORMAT("      HAVE YOU STORED THE MEASUREMENTS AS A DATA FILE?" /,
      - "      ANSWER Y/N " /)
      READ(1,40) REE
40  FORMAT(A1)
      IF (REE .NE. "N" .AND. REE .NE. "Y") GO TO 20
      IF (REE .IS. "N") GO TO 220
50  WRITE(1,60)
60  FORMAT("      ARE YOU INTRODUCING A NEW DATA FILE ? Y OR N " /)
      READ(1,70) RE
70  FORMAT(A1)
      IF (RE .NE. "N" .AND. RE .NE. "Y") GO TO 50
      IF (RE .IS. "N") GO TO 80
      CALL SCREEN
      CALL CALC

```

```

      CALL CON
      CALL CHNG
      CALL FASE
90  CALL QUS(N,ANS,REP,D,REPA,ANSA,T)
      IF (N .IS. "BF") GO TO 90
      IF (T .IS. "Y") GO TO 210
      IF (R .IS. "N") GO TO 210
      IF (N .IS. "NON") GO TO 210
      IF (N .IS. "FA" .AND. N .IS. "BA") GO TO 180
90  L = L
100 CALL SCREEN
      CALL PICCLE
      CALL DRSKIN(N,R)
      CALL SCREEN
110 WRITE(1,120)
120 FORMAT("      WOULD YOU LIKE TO DRAW BLOCK?Y/N" /)
      READ(1,130) E
130 FORMAT(A2)
      IF (E .NE. "N" .AND. E .NE. "Y") GO TO 110
      IF (E .IS. "N") GO TO 140
      CALL BROKEN(1)
      CALL DRBLOK(N,R)
      CALL SCREEN
      CALL CHAMOD
140 WRITE(1,150)
150 FORMAT("      WOULD YOU LIKE TO PLOT? IF YES WHICH PATTERN?" /,
- "      SK FOR SKIN  BL FOR BLOCK  BOT FOR BOTH IF NO N" /)
      READ(1,160) R
160 FORMAT(A3)
      IF (R .NE. "SK" .AND. R .NE. "BL" .AND. R .NE. "BOT" .AND. R .
NE.
- "N") GO TO 140
      IF (R .IS. "BOT") GO TO 170
      IF (R .IS. "N") GO TO 180
      IF (R .IS. "SK") CALL SKIN(N,R)
      IF (R .IS. "SK") GO TO 140
      IF (R .IS. "BL") CALL BLOCK(N,R)
      IF (R .IS. "BL") GO TO 140
      CALL DEVEND
      GO TO 180
170 CALL DEVEND
      CALL PLOT(REPA,REP,N)
      CALL DRSKIN(N,R)
      CALL BROKEN(1)
      CALL TRANSF(2)
      CALL DRBLOK(N,R)
      GO TO 140
180 WRITE(1,190)
190 FORMAT("      IS IT YOUR LAST PATTERN? Y OR N " /)
      READ(1,200) P
200 FORMAT(A1)
      IF (P .NE. "N" .AND. P .NE. "Y") GO TO 180
      IF (P .IS. "Y") GO TO 210
      CALL SCREEN
      CALL PICCLE

```



```

      GO TO 80
210 CALL DEVEND
      GO TO 240
220 WRITE(1,230)
230 FORMAT("PLEASE ENTER YOUR DATA FILE FIRST")
240 STOP
      END
      SUBROUTINE QUS(N,ANS,REP,D,REPA,ANSA,T)
10 WRITE(1,20)
20 FORMAT("  WHICH PATTERN WOULD YOU LIKE TO SEE NEXT?" /,
- "    FA    FRONT PATTERN SHOULDER/WAIST DARTS    " /,
- "    BA    BACK PATTERN SHOULDER-WAIST DARTS      " /,
- "    BF    BOTH FA+BA ON SAME VIEW OR NON " /)
      READ(1,30) N
30 FORMAT(A3)
      IF (N .NE. "F" .AND. N .NE. "FA" .AND. N .NE. "B" .AND. N .NE.
- "BA" .AND. N .NE. "BF" .AND. N .NE. "NON") GO TO 10
      IF (N .IS. "NON") GO TO 50
      IF (N .IS. "BF") GO TO 50
      IF (N .IS. "FA") CALL FRONT(N,R,D)
40 IF (N .IS. "FA") CALL POL(N,R)
      IF (N .IS. "BA") CALL BACKAA(N,R,D)
      IF (N .IS. "BA") CALL POL(N,R)
      IF (N .IS. "FA" .OR. N .IS. "BA") GO TO 10
50 CALL DEVEND
      RETURN
      END
      SUBROUTINE PLOT(REPA,REP,N)
      CALL DEVEND
      CALL PLOTIN
      IF (N .IS. "FA") GO TO 10
      IF (N .IS. "BA") GO TO 20
      CALL DEVICE(3,100)
      GO TO 30
10 CALL DEVICE(23,100)
      GO TO 30
20 CALL DEVICE(25,100)
30 CALL UNITS(10.0)
      CALL DEVPAP(600.0,500.0,0)
      RETURN
      END
      SUBROUTINE SCREEN
      CALL T4010
      CALL DEVICE(1,10)
      CALL SCALE(2)
      RETURN
      END
      SUBROUTINE CALC
      INTEGER I,J,JJ,F,K
      DIMENSION DIST(50,50),DISTA(50,50),ANGLES(60,3)
      REAL X(41),Y(41),Z(41),DESC(4,41),SUBX(41),SUBY(41),SUBZ(41),D
IS  - (41),LEN(3),Q(3),MEN(2),B(41),BA,D,ZAVIT(60,3),DESK(4,41)
      I = 1
10 DO 40 I = 1,36

```

```

20 READ(11,30) (DESC(K,I),K = 1,4),X(I),Y(I),Z(I)
30 FORMAT(4A6,3F6.2)
40 CONTINUE
    DO 70 I = 1,36
50 READ(11,60) B(I)
60 FORMAT(F3.2)
70 CONTINUE
    DO 140 I = 1,35
        JJ = I + 1
80 DO 130 J = JJ,36
        SUBX(J) = (X(J) - X(I)) ** 2
        SUBY(J) = (Y(J) - Y(I)) ** 2
        SUBZ(J) = (Z(J) - Z(I)) ** 2
        DIS(J) = SQRT(SUBX(J) + SUBY(J) + SUBZ(J))
        IF (I .EQ. 30 .AND. JJ .EQ. 31) GO TO 100
90 DISTA(I,J) = DIS(J)
    GO TO 110
100 DISTA(I,J) = DIS(J) * 1.56
    GO TO 110
110 KK = 0
    * WRITE(7,120) J,(DESC(K,J),K = 1,4),X(J),Y(J),Z(J),DIS(J)
120 FORMAT(12X,I3,10X,4A6,13X,3F6.2,12X,F6.2)
130 CONTINUE
140 CONTINUE
    LOCK(7)
    DO 150 J = 1,20
        DIST(1,J) = DISTA(1,J)
150 CONTINUE
    GO TO 160
160 DO 170 J = 22,36
        DIST(21,J) = DISTA(21,J) * B(J)
170 CONTINUE
    DO 190 J = 22,36
        DIST(21,J) = DISTA(21,J) * B(J)
        WRITE(17,180) DIST(21,J)
180 FORMAT(F6.2,2X)
190 CONTINUE
    LOCK(17)
200 DO 220 I = 2,16,1
210 LEN(1) = DIST(1,I)
    LEN(2) = DIST(1,I + 1)
    LEN(3) = DISTA(1,I + 1)
    CALL ANGL(ANGLES,LEN,Q,I,II,LLL,LL,L,F) A
220 CONTINUE
    L = 17
    LEN(1) = DIST(1,L)
    LEN(2) = DIST(1,2)
    LEN(3) = DISTA(2,L)
    CALL ANGL(ANGLES,LEN,Q,I,II,LLL,LL,L,F) B
230 DO 250 I = 22,35
240 LEN(1) = DIST(21,I)
    LEN(2) = DIST(21,I + 1)
    LEN(3) = DISTA(1,I + 1)
    CALL ANGL(ANGLES,LEN,Q,I,II,LLL,LL,L,F) C
250 CONTINUE

```

```

I = 36
LEN(1) = DIST(21,I)
LEN(2) = DIST(21,22)
LEN(3) = DISTA(22,I)
CALL ANGL(ANGLES,LEN,Q,I,II,LLL,LL,L,F)
LOCK(8)
260 LL = 0
CALL TOTAL(ANGLES,TOT,TOTA,TOTB,TOTC,TOTD,TOTE,TOTF,TOTG)
CALL ZAV(ANGLES,ZAVIT,TOT,TOTA,TOTD,TOTE)
CALL CORD(LEN,I,ANGLES,DIST,DISTA,ZAVIT)
CALL ZAVTA(ZAVIT)
270 LOCK(7)
LOCK(3)
LOCK(9)
LOCK(11)
RETURN
END
SUBROUTINE ANGL(ANGLES,LEN,Q,I,II,LLL,LL,L,F)
REAL ANGLES(60,3),LEN(3),Q(3),COX,COY,COZ
JL = I - 1
IF (I .EQ. 17) JL = I
IF (I .EQ. 18) JL = I
IF (I .EQ. 19) JL = I
IF (I .EQ. 20) JL = I
IF (L .EQ. 17) JL = I - 1
IF (I .EQ. 37) JL = I
IF (I .EQ. 38) JL = I
IF (I .EQ. 39) JL = I
IF (I .EQ. 40) JL = I
IF (LL .EQ. 37) JL = I - 1
COX = (LEN(1) ** 2 + LEN(2) ** 2 - LEN(3) ** 2) / (2 * LEN(1)
*
- LEN(2))
Q(1) = ARCOS(COX)
COY = (LEN(1) ** 2 + LEN(3) ** 2 - LEN(2) ** 2) / (2 * LEN(1)
*
- LEN(3))
Q(2) = ARCOS(COY)
COZ = (LEN(2) ** 2 + LEN(3) ** 2 - LEN(1) ** 2) / (2 * LEN(2)
*
- LEN(3))
Q(3) = ARCOS(COZ)
DO 10 J = 1,3
ANGLES(JL,J) = Q(J)
10 CONTINUE
DO 30 J = 1,3
K = I - 1
WRITE(8,20) K,ANGLES(JL,J)
20 FORMAT(I3,2X,3(F6.2,2X))
30 CONTINUE
40 RETURN
END
SUBROUTINE CORD(LEN,I,ANGLES,DIST,DISTA,ZAVIT)
REAL ANGLES(60,3),DIST(50,50),X(60),Y(60),LEN(3),DISTA(50,50),
- ZAVIT(60,3)

```

```

T = 2
JL = I - 1
K = 2
Z = 0
X(K) = DIST(1,K) * COS(Z)
Y(K) = DIST(1,K) * SIN(Z)
DO 30 I = 1,5
IF (I .NE. 1) GO TO 10
ZM = 0
Z = ZM + (ZAVIT(I,1))
IF (I .EQ. 1) GO TO 20
10 Z = Z + ZAVIT(I,1)
20 J = I + 2
X(J) = DIST(1,J) * COS(Z)
Y(J) = DIST(1,J) * SIN(Z)
30 CONTINUE
I = 6
J = 7
JJ = I + 2
Z = Z + ZAVIT(I,1)
X(JJ) = DIST(1,J) * COS(Z)
Y(JJ) = DIST(1,J) * SIN(Z)
DO 50 I = 7,15
Z = Z + ZAVIT(I,1)
J = I + 1
JJ = I + 2
X(JJ) = DIST(1,J) * COS(Z)
GO TO 40
40 Y(JJ) = DIST(1,J) * SIN(Z)
50 CONTINUE
I = 16
60 J = I
JJ = I + 2
Z = Z + ZAVIT(I,1)
X(JJ) = DIST(1,J) * COS(Z)
Y(JJ) = DIST(1,J) * SIN(Z)
IF (I .EQ. 17) GO TO 70
I = 17
GO TO 60
70 I = 18
J = 2
JJ = I + 2
Z = Z + ZAVIT(I,1)
X(JJ) = DIST(1,J) * COS(Z)
Y(JJ) = DIST(1,J) * SIN(Z)
K = 22
Z = 0
X(K) = DIST(21,K) * COS(Z)
Y(K) = DIST(21,K) * SIN(Z)
80 DO 110 I = 21,24
IF (I .NE. 21) GO TO 90
ZM = 0
Z = ZM + (ZAVIT(I,1))
IF (I .EQ. 21) GO TO 100
90 Z = Z + ZAVIT(I,1)

```



```

100 J = I + 2
    X(J) = DIST(21,J) * COS(Z)
    Y(J) = DIST(21,J) * SIN(Z)
110 CONTINUE
    I = 25
    J = I + 1
    JJ = I + 2
    Z = Z + ZAVIT(I,1)
    X(JJ) = DIST(21,J) * COS(Z)
    Y(JJ) = DIST(21,J) * SIN(Z)
    DO 120 I = 26,34
        Z = Z + ZAVIT(I,1)
        J = I + 1
        JJ = I + 2
        X(JJ) = DIST(21,J) * COS(Z)
        Y(JJ) = DIST(21,J) * SIN(Z)
120 CONTINUE
    I = 35
130 J = I
    JJ = I + 2
    Z = Z + ZAVIT(I,1)
    X(JJ) = DIST(21,J) * COS(Z)
    Y(JJ) = DIST(21,J) * SIN(Z)
    IF (I .EQ. 36) GO TO 150
    I = 36
140 I = 36
    GO TO 130
150 I = 37
    J = 22
    JJ = I + 2
    Z = Z + ZAVIT(I,1)
    X(JJ) = DIST(21,J) * COS(Z)
    Y(JJ) = DIST(21,J) * SIN(Z)
160 CALL WORD(I,X,Y)
    RETURN
    END
    SUBROUTINE WORD(I,X,Y)
    INTEGER JL,J,L
    REAL X(60),Y(60),A,B
    A = 0.00
    B = 0.00
    L = 1
    JL = 1
    J = 1
    WRITE(9,10) L,JL,A,J,B
10  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    K = 2
    J = 2
    JL = 2
    L = 2
    A = X(K)
    B = Y(K)
    WRITE(9,20) L,JL,A,J,B
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    DO 40 I = 3,20

```

```

      J = I
      JL = I
      WRITE(9,30) I,JL,X(I),J,Y(I)
30  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
40  CONTINUE
      A = 0.00
      B = 0.00
      L = 21
      JL = 21
      J = 21
      WRITE(9,50) L,JL,A,J,B
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      K = 22
      J = 22
      JL = 22
      L = 22
      A = X(K)
      B = Y(K)
      WRITE(9,60) L,JL,A,J,B
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
70  DO 90 I = 23,39
      J = I
      JL = I
      WRITE(9,80) I,JL,X(I),J,Y(I)
80  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
90  CONTINUE
      LOCK(9)
      RETURN
      END
      SUBROUTINE ZAV(ANGLES,ZAVIT,TOT,TOTA,TOTD,TOTE)
      DIMENSION ANGLES(60,3),ZAVIT(60,3)
      REAL TOT,TOTA,TOTB,TOTC,TOTD,TOTE,TOTF,TOTG
      DO 20 JL = 1,5
      DO 10 I = 1,3
      ZAVIT(JL,I) = ANGLES(JL,I)
10  CONTINUE
20  CONTINUE
      JL = 6
      A = 3.14 - TOT
      DO 30 I = 1,3
      IF (I .EQ. 1) ZAVIT(JL,I) = TOT
      IF (I .EQ. 2) ZAVIT(JL,I) = A / 2
      IF (I .EQ. 3) ZAVIT(JL,I) = A / 2
30  CONTINUE
      DO 50 JL = 6,14
      DO 40 I = 1,3
      ZAVIT(JL + 1,I) = ANGLES(JL,I)
40  CONTINUE
50  CONTINUE
      JL = 16
      D = TOTA - TOT
      AB = 3.14-D
      DO 60 I = 1,3
      IF (I .EQ. 1) ZAVIT(JL,I) = D
      IF (I .EQ. 2) ZAVIT(JL,I) = AB / 2

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```

      IF (I .EQ. 3) ZAVIT(JL,I) = AB / 2
60  CONTINUE
      DO 80 JL = 15,16
      DO 70 I = 1,3
      ZAVIT(JL + 2,I) = ANGLES(JL,I)
70  CONTINUE
80  CONTINUE
      DO 100 JL = 21,24
      DO 90 I = 1,3
      ZAVIT(JL,I) = ANGLES(JL,I)
90  CONTINUE
100 CONTINUE
110 JL = 25
      E = TOTE - TOTD
      EL = E
      IF (EL .GT. 0) GO TO 120
      TOTD = TOTD + E
120 AC = 3.14 - TOTD
      DO 130 I = 1,3
      IF (I .EQ. 1) ZAVIT(JL,I) = TOTD
      IF (I .EQ. 2) ZAVIT(JL,I) = AC / 2
      IF (I .EQ. 3) ZAVIT(JL,I) = AC / 2
130 CONTINUE
      DO 150 JL = 25,33
      DO 140 I = 1,3
      ZAVIT(JL + 1,I) = ANGLES(JL,I)
140 CONTINUE
150 CONTINUE
      JL = 35
      GO TO 160
      G = 3.14
      E = TOTE - TOTD
      EL = E
      IF (E .GT. G) E = 0
      IF (E .NE. 0) GO TO 160
      L = EL - G
      TOTD = TOTD + L
      LL = 0
      GO TO 110
160 E = TOTE - TOTD
      IF (E .LT. 0) GO TO 210
      AD = 3.14-E
      DO 170 I = 1,3
      IF (I .EQ. 1) ZAVIT(JL,I) = E
      IF (I .EQ. 2) ZAVIT(JL,I) = AD / 2
      IF (I .EQ. 3) ZAVIT(JL,I) = AD / 2
170 CONTINUE
180 DO 200 JL = 34,35
      DO 190 I = 1,3
      ZAVIT(JL + 2,I) = ANGLES(JL,I)
190 CONTINUE
200 CONTINUE
      GO TO 240
210 DO 230 JL = 34,35
      DO 220 I = 1,3

```

```

      ZAVIT(JL + 1,I) = ANGLES(JL,I)
220 CONTINUE
230 CONTINUE
240 RETURN
      END
) SUBROUTINE TOTAL(ANGLES,TOT,TOTA,TOTB,TOTC,TOTD,TOTE,TOTF,TOTG

      REAL TOT,TOTA,TOTB,TOTC,TOTD,TOTE,TOTF,TOTG
      DIMENSION ANGLES(60,3)
      J = 1
      SUM = 0
      DO 10 I = 1,11
      SUM = SUM + ANGLES(I,J)
10 CONTINUE
      TOT = 3.14 - SUM
      DO 20 I = 12,16
      SUM = SUM + ANGLES(I,J)
20 CONTINUE
      TOTA = 6.28 - SUM
      GO TO 50
      J = 1
      SUM = 0
      DO 30 I = 1,13
      SUM = SUM + ANGLES(I,J)
30 CONTINUE
      TOTB = 6.28 - SUM
      DO 40 I = 16,20
      SUM = SUM + ANGLES(I,J)
40 CONTINUE
      TOTC = 6.28 - SUM
50 J = 1
      SUM = 0
      DO 60 I = 21,27
      SUM = SUM + ANGLES(I,J)
60 CONTINUE
      TOTD = 3.14 - SUM
      DO 70 I = 28,35
      SUM = SUM + ANGLES(I,J)
70 CONTINUE
      TOTE = 6.28 - SUM
      GO TO 100
      J = 1
      SUM = 0
      DO 80 I = 21,33
      SUM = SUM + ANGLES(I,J)
80 CONTINUE
      TOTF = 6.28 - SUM
      DO 90 I = 36,40
      SUM = SUM + ANGLES(I,J)
90 CONTINUE
      TOTG = 6.28 - SUM
100 RETURN
      END
      SUBROUTINE ZAVTA(ZAVIT)
      REAL ZAVIT(60,3)

```



```
WRITE(18,10) ((ZAVIT(I,J),J = 1,3),I = 1,60)
10 FORMAT(" ",3(F6.2,2X))
LOCK(18)
RETURN
END
```

APPENDIX 1 (CONTINUED)

```
SUBROUTINE CON
REAL X(60),Y(60),A,B
DO 30 I = 1,7
  READ(9,10) I,JL,X(I),J,Y(I)
10  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  WRITE(15,20) I,JL,X(I),J,Y(I)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
30  CONTINUE
  I = 8
  A = 0.00
  B = 0.00
  L = 8
  JL = 8
  J = 8
  WRITE(15,40) L,JL,A,J,B
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  DO 70 I = 8,17
    READ(9,50) I,JL,X(I),J,Y(I)
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    JL = I + 1
    J = I + 1
    WRITE(15,60) J,JL,X(I),J,Y(I)
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
70  CONTINUE
    A = 0.00
    B = 0.00
    L = 19
    JL = 19
    J = 19
    WRITE(15,80) L,JL,A,J,B
80  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    DO 110 I = 18,20
      READ(9,90) I,JL,X(I),J,Y(I)
90  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      JL = I + 2
      J = I + 2
      WRITE(15,100) J,JL,X(I),J,Y(I)
100 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
110 CONTINUE
    CALL BACK
    LOCK(9)
    LOCK(15)
    REWIND 15
    REWIND 9
    RETURN
  END
SUBROUTINE BACK
REAL X(60),Y(60),A,B
DO 30 I = 21,26
  READ(9,10) I,JL,X(I),J,Y(I)
  J = I + 2
  JL = I + 2
10  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  WRITE(15,20) J,JL,X(I),J,Y(I)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
```

```

30 CONTINUE
  I = 27
  A = 0.00
  B = 0.00
  L = I + 2
  JL = I + 2
  J = I + 2
  WRITE(15,40) L,JL,A,J,B
40 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  DO 70 I = 27,36
    READ(9,50) I,JL,X(I),J,Y(I)
50 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    JL = I + 3
    J = I + 3
    WRITE(15,60) J,JL,X(I),J,Y(I)
60 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
70 CONTINUE
  I = 37
  A = 0
  B = 0
  JL = I + 3
  J = 40
  WRITE(15,80) J,J,A,J,B
80 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  DO 110 I = 37,39
    READ(9,90) I,JL,X(I),J,Y(I)
90 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    JL = I + 4
    J = I + 4
    WRITE(15,100) J,JL,X(I),J,Y(I)
100 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
110 CONTINUE
  RETURN
  END
  SUBROUTINE DRSKIN(N,R)
  DIMENSION X(60),Y(60)
  IF (N .IS. "BF") GO TO 10
  CALL SHIF
  GO TO 20
10 CALL SHIFT2(20.0,25.0)
  CALL MOVT02(0.0,0.0)
20 CALL FRONT(N,R,D)
30 CALL SHIFT2(30.0,20.0)
  CALL MOVT02(0.0,0.0)
  CALL BACKAA(N,R,D)
  GO TO 50
40 CALL DEVEND
50 LOCK(9)
  LOCK(15)
  LOCK(16)
  REWIND 15
  REWIND 16
  RETURN
  END
  SUBROUTINE FRONT(N,R,D)

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```

    DIMENSION X(60),Y(60)
    IF (N .IS. "FA") CALL SHIF
10  C = 4
    READ(16,20) (I,JL,X(I),J,Y(I),I = 1,C)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(2),Y(2),C - 1)
    C = 6
    READ(16,30) (I,JL,X(I),J,Y(I),I = 4,C)
30  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL CURTO2(X(4),Y(4),3,0,0)
    C = 10
    READ(16,40) (I,JL,X(I),J,Y(I),I = 6,C)
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(6),Y(6),5)
    C = 14
    READ(16,50) (I,JL,X(I),J,Y(I),I = 10,C)
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL CURTO2(X(10),Y(10),5,0,0)
    C = 22
    READ(16,60) (I,JL,X(I),J,Y(I),I = 14,C)
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(14),Y(14),10)
    LOCK(15)
    REWIND 15
    LOCK(16)
    REWIND 16
    CALL CHAMOD
70  RETURN
    END
    SUBROUTINE BACKAA(N,R,D)
    DIMENSION X(60),Y(60)
    IF (N .IS. "BA") CALL SHIF
10  C = 25
    READ(16,20) (I,JL,X(I),J,Y(I),I = 23,C)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(24),Y(24),2)
    C = 27
    READ(16,30) (I,JL,X(I),J,Y(I),I = 25,C)
30  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL CURTO2(X(25),Y(25),3,0,0)
    C = 31
    READ(16,40) (I,JL,X(I),J,Y(I),I = 27,C)
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(27),Y(27),5)
    C = 35
    READ(16,50) (I,JL,X(I),J,Y(I),I = 31,C)
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL CURTO2(X(31),Y(31),5,0,0)
    C = 43
    READ(16,60) (I,JL,X(I),J,Y(I),I = 35,C)
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
    CALL POLTO2(X(35),Y(35),9)
    LOCK(15)
    REWIND 15
    LOCK(16)

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REWIND 16
CALL CHAMOD
70 RETURN
END
SUBROUTINE EASE
REAL X(60),Y(60),K(60),L(60),M(60),V(60)
DO 100 I = 1,43
  READ(16,10) I,JL,X(I),J,Y(I)
10  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
  READ(21,20) K(I),L(I)
20  FORMAT(F4.3,2X,F4.3)
  IF (I .EQ. 15) K(I) = K(I - 1)
  IF (I .EQ. 15) L(I) = L(I - 1)
  IF (I .EQ. 16) L(I) = L(I - 2)
  IF (I .EQ. 16) K(I) = K(I - 2)
  IF (I .EQ. 36) L(I) = L(I - 1)
  IF (I .EQ. 36) K(I) = K(I - 1)
  IF (I .EQ. 37) L(I) = L(I - 2)
  IF (I .EQ. 37) K(I) = K(I - 2)
  IF (I .EQ. 8) GO TO 30
  IF (I .EQ. 19) GO TO 40
  IF (I .EQ. 29) GO TO 30
  IF (I .EQ. 40) GO TO 50
  M(I) = (X(I)) * (K(I))
  V(I) = Y(I) * L(I)
  GO TO 60
30  M(I) = (X(I)) - K(I)
  V(I) = (Y(I) + L(I))
  GO TO 60
40  M(I) = (X(I)) - K(I)
  V(I) = (Y(I) - L(I))
  GO TO 60
50  M(I) = (X(I)) + K(I)
  V(I) = (Y(I) - L(I))
  GO TO 60
60  WRITE(22,70) M(I),V(I)
70  FORMAT(F10.5,2X,F10.5)
80  WRITE(20,90) M(I),V(I)
90  FORMAT(F10.5,2X,F10.5)
100 CONTINUE
  LOCK(15)
  REWIND 15
  LOCK(21)
  REWIND 21
  LOCK(22)
  REWIND 22
  LOCK(16)
  REWIND 16
  RETURN
END
SUBROUTINE DRBLOK(N,R)
REAL X(60),Y(60),K(60),L(60),M(60)
IF (N .IS. "BF") GO TO 10
CALL SHIF
GO TO 20

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10 CALL SHIFT2(20.0,25.0)
   CALL MOVTO2(0.0,0.0)
20 CALL FRONTA(N)
   CALL SHIFT2(30,20)
   CALL MOVTO2(0.0,0.0)
30 CALL BACKA
40 CALL DEVEND
   LOCK(9)
   LOCK(22)
   REWIND 22
   RETURN
   END
   SUBROUTINE FRONTA(N)
   REAL X(60),Y(60),K(60),L(60),M(60),V(60)
   C = 4
   READ(22,10) (X(I),Y(I),I = 1,C)
10  FORMAT(F10.5,2X,F10.5)
   CALL POLTO2(X(2),Y(2),C - 1)
   C = 6
   READ(22,20) (X(I),Y(I),I = 5,C)
20  FORMAT(F10.5,2X,F10.5)
   CALL CURTO2(X(4),Y(4),3,0,0)
   C = 10
   READ(22,30) (X(I),Y(I),I = 7,C)
30  FORMAT(F10.5,2X,F10.5)
   CALL POLTO2(X(6),Y(6),5)
   C = 14
   READ(22,40) (X(I),Y(I),I = 11,C)
40  FORMAT(F10.5,2X,F10.5)
   CALL CURTO2(X(10),Y(10),5,0,0)
   C = 22
   READ(22,50) (X(I),Y(I),I = 15,C)
50  FORMAT(F10.5,2X,F10.5)
   CALL POLTO2(X(14),Y(14),9)
   IF (N .IS. "BF") GO TO 60
   LOCK(22)
   REWIND 22
60  RETURN
   END
   SUBROUTINE BACKA
   REAL X(60),Y(60),K(180),L(180),M(180),V(180)
   I = 23
   C = 25
   READ(22,10) (X(I),Y(I),I = 23,C)
10  FORMAT(F10.5,2X,F10.5)
   CALL POLTO2(X(24),Y(24),2)
   C = 27
   READ(22,20) (X(I),Y(I),I = 26,C)
20  FORMAT(F10.5,2X,F10.5)
   CALL CURTO2(X(25),Y(25),3,0,0)
   C = 31
   READ(22,30) (X(I),Y(I),I = 28,C)
30  FORMAT(F10.5,2X,F10.5)
   CALL POLTO2(X(27),Y(27),5)
   C = 35

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      READ(22,40) (X(I),Y(I),I = 32,C)
40  FORMAT(F10.5,2X,F10.5)
      CALL CURTO2(X(31),Y(31),5,0,0)
      C = 43
      READ(22,50) (X(I),Y(I),I = 36,C)
50  FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(35),Y(35),9)
      LOCK(22)
      REWIND 22
      RETURN
      END
      SUBROUTINE FRO(N,R,D)
      DIMENSION X(60),Y(60)
      CALL SHIFT2(30.0,30.0)
      CALL MOVTO2(0.0,0.0)
10  C = 4
      READ(15,20) (I,JL,X(I),J,Y(I),I = 1,C)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL POLTO2(X(2),Y(2),C - 1)
      C = 6
      READ(15,30) (I,JL,X(I),J,Y(I),I = 4,C)
30  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL CURTO2(X(4),Y(4),3,0,0)
      C = 10
      READ(15,40) (I,JL,X(I),J,Y(I),I = 6,C)
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL POLTO2(X(6),Y(6),5)
      C = 14
      READ(15,50) (I,JL,X(I),J,Y(I),I = 10,C)
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL CURTO2(X(10),Y(10),5,0,0)
      C = 22
      READ(15,60) (I,JL,X(I),J,Y(I),I = 14,C)
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL POLTO2(X(14),Y(14),10)
      LOCK(15)
      REWIND 15
      CALL CHAMOD
70  RETURN
      END
      SUBROUTINE BAK(N,R,D)
      DIMENSION X(60),Y(60)
      CALL SHIFT2(30.0,30.0)
      CALL MOVTO2(0.0,0.0)
10  C = 25
      READ(15,20) (I,JL,X(I),J,Y(I),I = 23,C)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL POLTO2(X(24),Y(24),2)
      C = 27
      READ(15,30) (I,JL,X(I),J,Y(I),I = 25,C)
30  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      CALL CURTO2(X(25),Y(25),3,0,0)
      C = 31
      READ(15,40) (I,JL,X(I),J,Y(I),I = 27,C)
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)

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CALL POLTO2(X(27),Y(27),5)
C = 35
READ(15,50) (I,JL,X(I),J,Y(I),I = 31,C)
50 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
CALL CURTO2(X(31),Y(31),5,0,0)
C = 43
READ(15,60) (I,JL,X(I),J,Y(I),I = 35,C)
60 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
CALL POLTO2(X(35),Y(35),9)
LOCK(15)
REWIND 15
CALL CHAMOD
70 RETURN
END
SUBROUTINE FROT(N,R)
REAL X(60),Y(60),K(60),L(60),M(60),V(60)
CALL SHIFT2(30.0,30.0)
CALL MOVTO2(0.0,0.0)
10 C = 4
READ(22,20) (X(I),Y(I),I = 1,C)
20 FORMAT(F10.5,2X,F10.5)
CALL POLTO2(X(2),Y(2),C - 1)
C = 6
READ(22,30) (X(I),Y(I),I = 5,C)
30 FORMAT(F10.5,2X,F10.5)
CALL CURTO2(X(4),Y(4),3,0,0)
C = 10
READ(22,40) (X(I),Y(I),I = 7,C)
40 FORMAT(F10.5,2X,F10.5)
CALL POLTO2(X(6),Y(6),5)
C = 14
READ(22,50) (X(I),Y(I),I = 11,C)
50 FORMAT(F10.5,2X,F10.5)
CALL CURTO2(X(10),Y(10),5,0,0)
C = 22
READ(22,60) (X(I),Y(I),I = 15,C)
60 FORMAT(F10.5,2X,F10.5)
CALL POLTO2(X(14),Y(14),9)
LOCK(22)
REWIND 22
RETURN
END
SUBROUTINE BCK(N,R)
REAL X(60),Y(60),K(180),L(180),M(180),V(180)
CALL SHIFT2(30.0,30.0)
CALL MOVTO2(0.0,0.0)
10 C = 25
READ(22,20) (X(I),Y(I),I = 23,C)
20 FORMAT(F10.5,2X,F10.5)
CALL POLTO2(X(24),Y(24),2)
C = 27
READ(22,30) (X(I),Y(I),I = 26,C)
30 FORMAT(F10.5,2X,F10.5)
CALL CURTO2(X(25),Y(25),3,0,0)
C = 31

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      READ(22,40) (X(I),Y(I),I = 28,C)
40  FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(27),Y(27),5)
      C = 35
      READ(22,50) (X(I),Y(I),I = 32,C)
50  FORMAT(F10.5,2X,F10.5)
      CALL CURTO2(X(31),Y(31),5,0,0)
      C = 43
      READ(22,60) (X(I),Y(I),I = 36,C)
60  FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(35),Y(35),9)
      LOCK(22)
      REWIND 22
      RETURN
      END
      SUBROUTINE SKIN(N,R)
      CALL DEVEND
      CALL PLOTIN
      CALL DEVICE(27,100)
      CALL UNITS(10.0)
      CALL DEVPAP(600.0,400.0,0)
      CALL DRSKIN(N,R)
      RETURN
      END
      SUBROUTINE BLOCK(N,R)
      CALL DEVEND
      CALL PLOTIN
      CALL DEVICE(29,100)
      CALL UNITS(10.0)
      CALL DEVPAP(600.0,400.0,0)
      CALL DRBLOK(N,R)
      RETURN
      END
      SUBROUTINE SHIF
      CALL DEVEND
      CALL SCREEN
      CALL SHIFT2(30.0,30.0)
      CALL MOVTO2(0.0,0.0)
      RETURN
      END
      SUBROUTINE FRA
      REAL X(60),L(60),K(60),Y(60)
      DO 30 I = 1,21
      READ(31,10) K(I),L(I)
10  FORMAT(1X,F5.2,2X,F5.2)
      X(I) = (K(I) * 1.00)
      Y(I) = (L(I) * 1.00)
      WRITE(32,20) X(I),Y(I)
20  FORMAT(F8.4,2X,F8.4)
30  CONTINUE
      LOCK(31)
      REWIND 31
      LOCK(32)
      REWIND 32
      RETURN

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END
SUBROUTINE BKA
REAL X(60),L(60),K(60),Y(60)
DO 30 I = 1,23
  READ(33,10) K(I),L(I)
10 FORMAT(1X,F5.2,2X,F5.2)
  X(I) = (K(I) * 1.00)
  Y(I) = (L(I) * 1.00)
  WRITE(34,20) X(I),Y(I)
20 FORMAT(F8.4,2X,F8.4)
30 CONTINUE
  LOCK(34)
  LOCK(33)
  REWIND 34
  REWIND 33
  RETURN
END
SUBROUTINE POL(N,R)
10 WRITE(1,20)
20 FORMAT("      WOULD YOU LIKE TO DRAW BLOCK?Y/N" /)
  READ(1,30) E
30 FORMAT(A2)
  IF (E .NE. "N" .AND. E .NE. "Y") GO TO 10
  IF (E .IS. "N") GO TO 60
  CALL BROKEN(1)
  IF (N .IS. "BA") GO TO 40
  CALL FRONTA(N)
  GO TO 50
40 CALL DUMMY(N)
  CALL BROKEN(1)
  CALL BACKA
50 CALL CHAMOD
  READ(1)
  CALL PICCLE
60 WRITE(1,70)
70 FORMAT("      WOULD YOU LIKE TO PLOT?IF YES WHICH PATTERN?/"
- "      SK FOR SKIN  BL FOR BLOCK  BOT FOR BOTH IF NO N" /)
  READ(1,80) R
80 FORMAT(A3)
  IF (R .NE. "SK" .AND. R .NE. "BL" .AND. R .NE. "BOT" .AND. R .
NE.
- "N") GO TO 60
  IF (R .IS. "BOT") GO TO 90
  IF (R .IS. "N") GO TO 100
  IF (R .IS. "SK") CALL SKINA(N,R,D)
  IF (R .IS. "SK") GO TO 60
  IF (R .IS. "BL") CALL BLOCKA(N,R,D)
  IF (R .IS. "BL") GO TO 60
  CALL DEVEND
  GO TO 100
90 CALL DEVEND
  CALL PLOT(REPA,REP,N)
  IF (N .IS. "FA") CALL FRO(N,R,D)
  IF (N .IS. "BA") CALL BAK(N,R,D)
  CALL BROKEN(1)

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      CALL TRANSF(2)
      IF (N .IS. "FA") CALL FROT(N,R)
      IF (N .IS. "BA") CALL BCK(N,R)
      GO TO 60
100 L = L
      CALL SCREEN
      CALL PICCLE
110 RETURN
      END
      SUBROUTINE SKINA(N,R,D)
      CALL DEVEND
      CALL PLOTIN
      IF (N .IS. "BA") GO TO 10
      CALL DEVICE(40,100)
      GO TO 20
10 CALL DEVICE(41,100)
20 CALL UNITS(10.0)
      CALL DEVPAP(600.0,500.0,0)
      IF (R .IS. "SK") CALL SUN
      IF (N .IS. "BA") CALL BAK(N,R,D)
      CALL FRO(N,R,D)
      D = 0
      RETURN
      END
      SUBROUTINE BLOCKA(N,R,D)
      CALL DEVEND
      CALL PLOTIN
      IF (N .IS. "BA") GO TO 10
      CALL DEVICE(42,100)
      GO TO 20
10 CALL DEVICE(43,100)
20 CALL UNITS(10.0)
      CALL DEVPAP(600.0,500.0,0)
      IF (R .IS. "BL") CALL SUN
      IF (N .IS. "BA") CALL BCK(N,R)
      CALL FROT(N,R)
      D = 0
      RETURN
      END
      SUBROUTINE SUN
      D = 1
      RETURN
      END
      SUBROUTINE DUMMY(N)
      REAL X(60),Y(60),K(60),L(60),M(60),V(60)
      CALL DUN(N,R)
      C = 4
      READ(22,10) (X(I),Y(I),I = 1,C)
10 FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(2),Y(2),C - 1)
      C = 6
      READ(22,20) (X(I),Y(I),I = 5,C)
20 FORMAT(F10.5,2X,F10.5)
      CALL CURTO2(X(4),Y(4),3,0,0)
      C = 10

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      READ(22,30) (X(I),Y(I),I = 7,C)
30  FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(6),Y(6),5)
      C = 14
      READ(22,40) (X(I),Y(I),I = 11,C)
40  FORMAT(F10.5,2X,F10.5)
      CALL CURTO2(X(10),Y(10),5,0,0)
      C = 22
      READ(22,50) (X(I),Y(I),I = 15,C)
50  FORMAT(F10.5,2X,F10.5)
      CALL POLTO2(X(14),Y(14),9)
      CALL SCREEN
      CALL SHIFT2(30.0,30.0)
      CALL MOVT02(0.0,0.0)
60  RETURN
      SUBROUTINE DUN(N,R)
      CALL DEVEND
      CALL PLOTIN
      CALL DEVICE(30,100)
      CALL UNITS(10.0)
      CALL DEVPAP(600.0,500.0,0.0)
      CALL SHIFT2(30.0,30.0)
      CALL MOVT02(0.0,0.0)
      RETURN
      END
      SUBROUTINE CHNG
      DIMENSION X(60),Y(60)
      DO 30 I = 1,13
      READ(15,10) I,JL,X(I),J,Y(I)
      IF (I .EQ. 2) X(I) = X(I) + 0.4
      IF (I .EQ. 3) X(I) = X(I) + 0.2
      IF (I .EQ. 11) X(I) = X(I) + 0.3
10  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,20) I,JL,X(I),J,Y(I)
20  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
30  CONTINUE
      I = 14
      L = I + 1
      K = I + 1
      Q = I + 2
      READ(15,40) I,JL,X(I),J,Y(I)
40  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,50) I,JL,X(I),J,Y(I)
50  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,60) K,K,X(I),L,Y(I)
60  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,70) Q,Q,X(I),Q,Y(I)
70  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      DO 90 I = 15,16
      READ(15,80) I,JL,X(I),J,Y(I)
80  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
90  CONTINUE
      DO 120 I = 17,34
      READ(15,100) I,JL,X(I),J,Y(I)
100 FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)

```



```

      IF (I .EQ. 22) X(I) = X(I) + 0.4
      WRITE(16,110) I,JL,X(I),J,Y(I)
110  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
120  CONTINUE
      I = 35
      L = I + 1
      K = I + 1
      Q = I + 2
      READ(15,130) I,JL,X(I),J,Y(I)
130  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,140) I,JL,X(I),J,Y(I)
140  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,150) K,K,X(I),K,Y(I)
150  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,160) Q,Q,X(I),Q,Y(I)
160  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      DO 180 I = 36,37
      READ(15,170) I,JL,X(I),J,Y(I)
170  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
180  CONTINUE
      DO 210 I = 38,43
      READ(15,190) I,JL,X(I),J,Y(I)
190  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
      WRITE(16,200) I,JL,X(I),J,Y(I)
200  FORMAT(15X,I3,20X,"X",I3,"=",F6.2,2X,"Y",I3,"=",F6.2)
210  CONTINUE
      LOCK(15)
      REWIND 15
      LOCK(16)
      REWIND 16
      RETURN
      END

```

APPENDIX 2 : DEFINITION OF VARIABLES USED IN THE COMPUTER PROGRAM

<u>Variable Name</u>	<u>Variable Type</u>	<u>Variable Description</u>
REE, RE, N, R, E, P.	String	Used to hold replies typed in.
I, JJ, J, K.	Integer	Used as counters in loops.
DIST	Array	An array containing the distances between the crucial shaping points.
ANGLES	Array	An array containing the triangular section's angles.
X, Y, Z.	Real	All receive the values of the three-dimensional co-ordinates of the crucial shaping points.
DESC	Array	An array containing the descriptions of the crucial shaping points.
SUB X (I)	Real	Receives the distances calculated between X_n and X_{n+1}
SUB Y (I)	Real	Receives the distances calculated between Y_n and Y_{n+1}
SUB Z (I)	Real	Receives the distances calculated between Z_n and Z_{n+1}
LEN	Real	Receives the distance between the crucial shaping points.

APPENDIX 2 (continued)


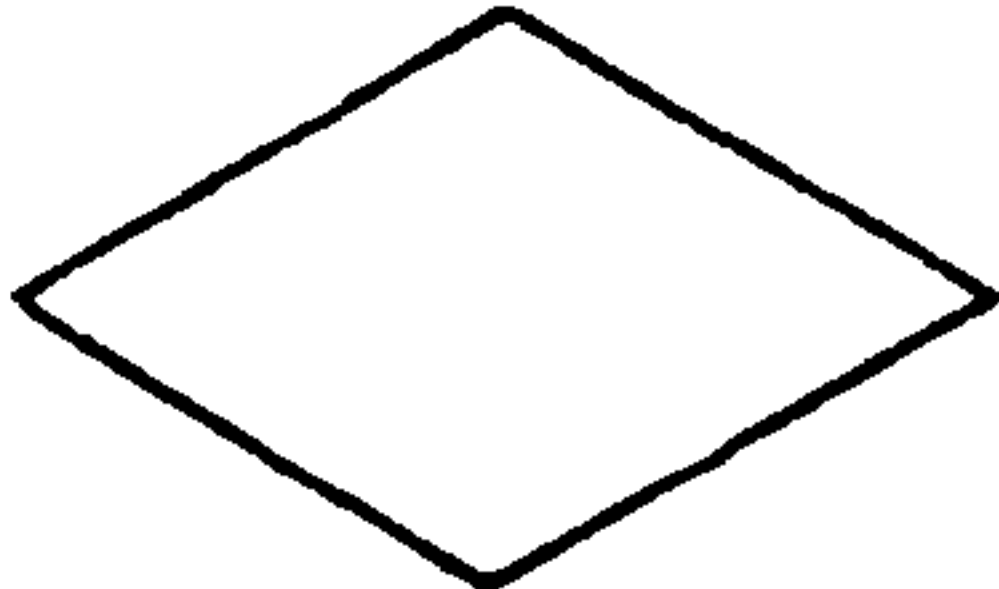


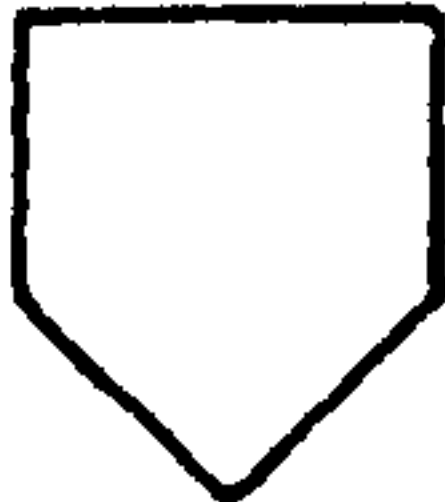
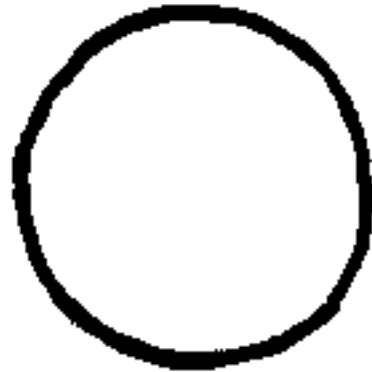
<u>Variable Name</u>	<u>Variable Type</u>	<u>Variable Description</u>
COX, COY, COZ	Real	Receives the cosign of the distances calculated for each per of values.
Q	Real	Receives the angle value.
ZAVIT	Array	An array containing the angles after dart distribution.
X, Y	Real	Receives the value of the two dimensional co-ordinates of the crucial shaping points.
TOT, TOTA, TOTD, TOTE.	Real	Receives the values of the angle of dart of each part of each panel.

APPENDIX 3 : SPECIFICATION OF FLOW CHARTING SYMBOLS USED

The flow chart symbols used in this thesis conform to the International Organisation for Standardised Recommendation on Flow Chart Symbols.

The flow of information is assumed to be from top to bottom and left to right unless a flow line contains an arrow which indicates a different direction.

The following are the symbols used:

<u>Flow Chart Symbol</u>	<u>Description</u>
	Pre-defined process
	Decision
	Call 'Routine'
	Start Enter Stop Return
	Off page connector
	On page connector

APPENDIX 4 : GENERAL COMMENTS ON THE FIT OF THE GARMENTS

<u>Size</u>	<u>Panel</u>	<u>Comments</u>		
		<u>Peter Gildroy</u>	<u>Jane Bristow</u>	<u>Anne Forbes</u>
10	Front	Dart gives a good fit.	Slight bagging under bust.	Excess of fabric under bust.
	Back	Slight surplus at armhole.	Slight surplus at armhole.	Slight surplus at armhole.
12	Front	Very good fit.	Slightly too wide.	Excess of fabric under bust.
	Back	Poking at dart point.	Poking at dart point.	Excess of fabric at dart point.
14	Front	Very good fit.	Very good fit.	Poking at dart point.
	Back	Slightly too wide.	Poking at dart point.	Excess of fabric.
16	Front	Slight surplus of fabric at armhole.	Slight surplus of fabric at armhole.	Slight surplus of fabric at armhole.
	Back	Very good fit.	Poking at dart point.	Poking at dart point.

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REFERENCES

1. Renbourn, E.T., Materials and Clothing in Health and Disease; H.K. Lewis, 1972.
2. Yarwood, D., English Costume, Batsford, 1961.
3. Waugh, N., The Cut of Men's Clothes 1600-1800. London, Faber 1964.
4. Melliar, M., Pattern Cutting, Batsford, 1968.
5. Mori, M., Basic Pattern Cutting, Batsford, 1970.
6. Day, L.F., Pattern Design, Batsford, 1979.
7. Handford, J., Professional Pattern Making for Designers of Women's wear, Plycon, 1977.
8. Curtis, I.E., Fundamental Principles of Pattern Making of Misses and Women's Garments, Curtis, 1966.
9. Cain, G., The American Way of Designing, New York, Fairchild Pub. Inc., 1950.
10. Morris, F.R., Ladies Garment Cutting and Making Up, New Era Pub. Co. Ltd.
11. Link, N.W., Precision Draping, De Vereaux Pub. 1947.
12. Hutchinson, R., The Geometrical Requirements of Patterns for Women's Garments to Achieve Satisfactory Fit, Leeds University, M.Sc. Thesis, 1977.
13. Simons, H., The Science of Human Proportions, New York, Clothing Designer Co. Inc., 1933.
14. Fourn, L. and Hollies, R., Clothing Comfort and Function, New York, Marcel Dekker Inc., 1970.
15. Forziati, F., Clothes that Fit Consumers All, 1965, Yearbook of Agriculture, Washington US Department of Agriculture.
16. O'Brien, R. and Shelton, W., Women's Measurements for Garment and Pattern Construction, U.S. Dept. of Agriculture, Miscellaneous Pub. No. 454, Washington U.S.A., 1941.
17. Churchill, T., Churchill, E., Laubach, L., Conville, J. and White, R., Anthropometry of Women's Figures in the U.S. Army, U.S. Army Research and Development Command, Natick 1977.
18. Kemsley, W.F.F., Annals of Eugenics (three papers), H.M.S.O., 1950, 1952 and 1953.
19. Joint Clothing Council, Women's Measurements and Sizes, H.M.S.O., 1957.
20. Bolton, C.B., An Anthropometric Survey of 2,000 Royal Air Force Aircrew; R.A.F. Publications, 1971.
21. Ince, N.E., Anthropometry of 500 Royal Armoured Corps Servicemen, Army Publications, 1972.

22. Whife, A.A., Designing and Cutting Ladies Garments, The Tailor and Cutter Ltd., 1965.
23. Lythe, G., Computer Aided Design, Patterns that Fit, C.F.I. Conference, May 1981.
24. Universal Ltd., Private Communications. 1980.
25. The Burton Group Ltd., Advertisement published in the T.V. Times Magazine, October 1981.
26. Pepin, H., Modern Pattern Design, New York, Funk and Wagnalls, 1942.
27. Brockman, H., The Theory of Fashion Design, New York, J. Wiley and Sons Inc., 1965.
28. Harron, R.E., Orthopaedic Review, 1975.4,12.
29. Du Bois, D. and Du Bois, E.F., A Height-Weight Formula to Estimate the Surface Area of Man. Proc. Soc. Exp. Biol. Med. 1916, 13.
30. Weinbach, A.P., Contour Maps, Centre of Gravity, Movement of Inertia and Surface Area of the Human Body, Human Biol. 1938, 10.
31. Geoghegan, B., The Determination of Body Measurements, Surface Area and Body Volume by Photography, An. J. Phys. Anthropol. 1953, 11.
32. Herzberg, H.T.E., Dupertius, C.W. and Emanuel, I., Stereophologrammetry as an Anthropometric Tool, Photogram, Eng. 1957, 23.
33. Weissman, S., Anthropometric Photogrammetry, Photogram. Eng. Oct. 1968.
34. Sangermano, J.C., Science Comes to an Ancient Art of Tailoring, The Cutting Room of the Future, Conference Proc. - A.A.M.A., G.I.T., U.S.A., 1977.
35. Lowrey, W.U., The Importance of Good Fit. Conf. Proc. A.A.M.A., 1977.
36. The Oxford Dictionary, Oxford University Press, Oxford, 1979.
37. Chamber, H., Wiley, E., Clothing Selection, New York, 1967.
38. Erwin, M.D., Clothing for Moderns, New York, The Macmillan Comp. 1957.
39. Minott, J., Co-ordinated Pattern Fit, Minneapolis Burges Pub. 1969.
40. Eddy, J. and Wiley, E., Pattern and Dress Design, New York, Houghton Mifflin Comp., 1932.
41. Siemans, E., A Comparison of the Sizes and Shapes of Dress Patterns made by Five Commercial Basic Patterns, M.Sc. Thesis, Texas University, August 1961.
42. Disney, P.A., A Comparison of Sizes and Shapes of Certain Commercial Available Dress Patterns, M.A. Thesis, Arizona University, 1961.

43. Robinson, O., Clothing Institute Journal, 1962, 10, 287.
44. Frankel, M., Clothing Institute Journal, 1970, 18, 393.
45. K.S.A., The 1980's - The Decade for Technology, Report prepared for the E.E.C. Commission, 1979.
46. Fakken, J., Clothing Institute Journal, 1973, 21, 199.
47. Disher, M., Bespoke Figuration by Computer, Clothing Manufacturer, July 1980.
48. Walton, A.R., Introduction to Burroughs 6700 Concepts, Oct. 1974.
49. Mitchelson, D.L., Movement Techniques Ltd., Private Communications.
50. 'British Male Body Measurements', Leeds, WIRA, 1980.